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PROCEEDINGS PUBLIC MEETING ON WATER QUALITY MANAGEMENT FOR ESTUARIES, HELD 28-29 JANUARY 1969, AT PAGODA HOTEL, HONOLULU, HAWAII

Federal Water Pollution Control Administration
San Francisco, California

29 January 1969

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CLEAN WATER

....FOR THE NATION'S ESTUARIES

PROCEEDINGS
PUBLIC MEETING
ON
WATER QUALITY MANAGEMENT
FOR ESTUARIES
HONOLULU, HAWAII
JANUARY 28-29, 1969

March 3, 1849

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PROCEEDINGS

PUBLIC MEETING
on
WATER QUALITY MANAGEMENT FOR ESTUARIES

Details of Illustrations in
this document may be better
studied on microfiche.

STATE OF HAWAII

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

January 28-29, 1969

Pagoda Hotel
Honolulu, Hawaii

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CLEAN WATER ....FOR THE NATION'S ESTUARIES

INVITATION

PUBLIC MEETING ON
WATER QUALITY MANAGEMENT FOR ESTUARIES

As a cooperative endeavor, the State of Hawaii and the Federal Water Pollution Control Administration will cosponsor a state-wide estuarine public meeting on January 28-29, 1969, at Honolulu, Hawaii. The meeting will be held in the West Room, Pagoda Hotel, 1525 Rycroft Street, and is scheduled to begin at 9 a.m. each day.

Under mandate of Congress, the U. S. Department of the Interior's Federal Water Pollution Control Administration is responsible for the preparation of a comprehensive report on the status of pollution in the Nation's estuaries. The report will include:

1. an analysis of the importance of estuaries to the economic and social well-being of the people of the United States and of the effects of pollution upon the use and enjoyment of such estuaries;

2. a discussion of the major economic, social and ecological trends occurring in the estuarine zones of the Nation; and

3. recommendations for a comprehensive national program for the preservation, study, use and development of estuaries of the Nation, and the respective responsibilities which should be assumed by Federal, State and local governments and by public and private interests.

This public meeting will provide an opportunity for individuals, groups, associations and organizations having an interest in the estuaries in the State of Hawaii and the problems related thereto, to make their views known.

Presentations may be either written or oral. If written, three copies, preferably typed, should be available for the record. An oral summary of the statement may be given at the meeting if so desired. Those anticipating presentation of statements, or if additional information on the meeting is needed, should call or write either:

Mr. Donald B. Mausshardt, Basin Engineer
Pacific Islands Basin Office, FWPCA
Pacific Southwest Region
1481 South King Street, Room 423
Honolulu, Hawaii 96814 Phone: (808) 949-5923

or

Mr. Irving M. Terzich
FWPCA, Pacific Southwest Region
760 Market Street
San Francisco, California 94102 Phone: (415) 556-7637

by January 22, 1969, to facilitate adequate time scheduling for presentations. Written statements for the record will be accepted until February 17, 1969.

To accommodate the greatest number of participants, meeting sessions will be planned for the morning, afternoon and evening of the first day. If the volume of presentations warrants, the morning of the second day will be scheduled to hear additional statements.

Attachments
1. Guidelines for Public Meeting
2. National Estuarine Pollution Study

CLEAN WATER ....FOR THE NATION'S ESTUARIES

GUIDELINES FOR PRESENTATIONS AT PUBLIC MEETING ON WATER QUALITY MANAGEMENT FOR ESTUARINE AREAS STATE OF HAWAII

January 28-29, 1969

The estuary system of Hawaii includes its tidal waters, the shore and adjacent land, and the biology and ecology of the coastal areas. It is this total resource on which we wish to receive information at the January 28-29, 1969 public meeting.

We will be particularly interested in your answers and position on the following types of questions:

> What are the values (aesthetic, personal, recreational, dollar, etc.) of an estuary?
> How have they been damaged by pollution, and how much?
> What do you think the future of our coastal zones should be?
> What are the best uses of our estuaries?
> What system of management--local, State and Federal--will best provide for development and protection of our estuarine resources?

You may have other pertinent points to raise. We are interested in hearing what you have to say on the subject of pollution, its effects, and its control in our estuaries.

To provide for an orderly meeting with time available for all, the following guides are established:

1. Statements should be concise and based upon the subjects of estuarine pollution and its effects on beneficial uses. It is suggested that lengthy statements be filed in writing for inclusion in the meeting record, and a brief summary of the statement presented orally.

2. A screen, blackboard, easel and projection equipment (2" x 2" 33 mm slides) will be provided for those wishing to accompany their presentation with visual aids. Special visual aids will be the responsibility of those making presentations.

FOREWORD

The public meeting transcript which follows is an important part of the National Estuarine Pollution Study. In the Clean Waters Restoration Act of 1966, Congress directed the Secretary of the Interior to conduct a study of the Nation's estuaries and to submit a report thereon by November, 1969. The report is to include recommendations for a comprehensive national program for the preservation, use and development of the estuaries; and the respective responsibilities which should be assumed by Federal, State and local governments, and by public and private interests. Jointly sponsored by the State of Hawaii and the Pacific Southwest Region, Federal Water Pollution Control Administration the meeting provided an opportunity for all interested individuals and organizations to express their views on water quality management for the estuaries of the State of Hawaii.

1-a

TRANSCRIPT

January 28, 1969
Pagoda Hotel

MR. CHAIRMAN: Aloha and good morning ladies and gentlemen. Welcome to your meeting. My name is Paul De Falco Jr., and I am Regional Director for the Pacific Southwest Region of the Federal Water Pollution Control Administration. The purpose of this meeting is to receive your views on the impact of pollution on Hawaii's estuary system.

Certainly in this fair State, perhaps more than any other, these waters are among your most priceless resources. This public meeting is the first of three being planned for the Pacific Southwest Region, and the only one in Hawaii. The two others will be held next month in San Francisco and Los Angeles. To date such meetings have been held in 22 coastal States.

In a few moments you will be asked to express your views on this important subject. And you will be presenting them to this panel. The panel is not here to judge or cross examine. They want to hear and to understand what you have to say. Occasionally the panel may ask questions of the speaker to clarify a point or guide the discussions to bring out views on an important issue.

Debate of issues is not a proper function of this meeting. I would like now for you to meet the panel. On my right is Dr. Walter Quisenberry, Director of the Hawaii Department of Health. On my left is Mr. Shinji Soneda, Executive Officer, Environmental Health Division, Department of Health, and Mr. Don Mausshardt, Director of the Pacific Island Basin of the Federal Water Pollution Control Administration.

At this point I would like to ask Dr. Quisenberry if he would like to give a few opening remarks.

DR. QUISENBERRY: Thank you very much, Mr. De Falco. I am very happy to have the opportunity of participating in this hearing with the Federal representatives of the Federal Water Pollution Control Administration. First, I thought just an explanation as to the status of the Department of Health in water pollution control. I think most of you are well acquainted with this, but perhaps some are not and there might be some question in your mind.

The Department of Health has been designated by the legislature, by the Governor, as the State Agency to coordinate the State efforts in water pollution control and to draw up water quality standards. I would like to express appreciation to the Governor, to the Legislature, and all the other 16 Departments of the State Government, and the other agencies of the State and the County for their assistance and cooperation in the work that we have done in water pollution control, and in the drawing up of the water quality standards, which we have drawn up.

I would like especially to express appreciation for the understanding which you have shown of the problems which we have faced in carrying out the responsibilities, which have been assigned to us. Also, I don't want to overlook all the private agencies and companies, and the public in general as individuals and as groups, for the assistance they have given, as all of you have given in the hearings and studies which we have conducted to date.

Sometimes the actions we have had to take have not been too popular, not too well received, but I think as we have a chance to explain things we have had to do, you have expressed a very fine understanding of the job we face. I'd like then, from the basis of that to ask for your further assistance and cooperation, and understanding again in the future of our programs. And as we go into the implementation of the water pollution program, and as we study further our problems such as the ones that will be discussed today in regards to the estuaries or the estuarine zone, I'd like at this time then to call on Mr. Soneda, who as you know, is the Executive Officer of our Environmental Health Division and he carries considerable responsibility in our water pollution control program.

He will introduce his staff members and will make a brief statement regarding our water pollution control activities in the past.

MR. SONEDA: The discussions we are going to hear today--actually, we have covered one way or the other in the 20 or so hearings that were conducted by either Mr. Dodge as the Master, or by Dr. Quisenberry of the Department of Health. But we appreciate this additional opportunity given by the FWPCA to look at this particular problem from a slightly different angle and we hope that this meeting today will be productive to everyone concerned.

I would like to introduce some of the other members of the Department of Health actively engaged in this particular program. Mr. Sakai, who is in charge of the Sanitary Engineering Branch, and the two staff engineers, Mr. Nakahara and Mr. Tulang. We have also here today a member of our Environmental Health Division of Kauai, Mr. Takamura and Mr. Koga from Hawaii.

MR. CHAIRMAN: Many of you have read our announcements regarding this meeting and are familiar with our study, but for those of you who are not, I would like to call on Mr. James C. McCarty, our Regional Coordinator for the National Estuarine Pollution Study in the Pacific Southwest Region to present a brief statement on the legislative background of this study and his activities to date. Jim?

MR. MC CARTY: Aloha! Thank you, Paul. Ladies and gentlemen, Dr. Quisenberry. The National Estuarine Pollution Study was authorized by the Congress through passage of the Clean Water Restoration Act of 1965. This particular provision of the Act is completely different and distinct from the Water Quality Standard Provision. I will try to give you an idea of the general nature of the Water Pollution Program.

The Act directs the Secretary of the Department of the Interior in cooperation with many public and private interests concerned to conduct a comprehensive study of the Nation's estuaries. Specifically, this study will

determine the present state of pollution;
delineate pollution problems requiring further study;
evaluate the effects of pollution on beneficial uses;
document the values of estuarine zones;
provide a basis of action for the beneficial management of the Nation's estuaries.

There are many definitions of an estuary. The Federal Act has defined the term "estuarine zone" for purposes of this study as:

> "an environmental system consisting of an estuary and those transitional areas which are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and intertidal areas, bays, harbors, lagoons, inshore waters and channels. . ."

The Act further defines the term "estuary", as opposed to estuarine zones, to mean:

> "all or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connection with the open sea and within which the sea water is measurably diluted with fresh water from land drainage."

Thus, for the purposes of this study, you can see we are really concerned with all coastal and estuarine waters, the land areas which might affect these waters and the total management of these land and water resources.

The study is to be completed and a report made to the Congress by November of this year.

The responsibility for coordinating the study and preparing a response to Congress was assigned to the Federal Water Pollution Control Administration. The Act specifies that the report to the Congress must include, and again I quote: "Recommendations for a comprehensive national program for the preservation, study, use and development of the estuaries of the nation; and the respective responsibilities which should be assumed by the Federal, State, and local governments and by public and private interests."

We are using a three-pronged approach to accomplish this effort.

First, the estuaries themselves are being examined. A description of the national system is being composited in terms of what it is, how it functions and how it has been damaged by pollution.

Next, the social and economic pressures on the estuary system are being studied. Resource use and the economic and social value of each use is being documented to establish the relative importance of these factors to the estuarine system.

The first two phases will provide an estuarine register--a comprehensive inventory, which is a necessary base for any management plan.

This brings us to the third phase--the development of recommendations for submission to the Congress. This is the most important phase and must include the needs and desires of the public. This is the primary reason we are gathered here today. Your remarks will be recorded in an official transcript from which recommendations will be prepared on all of the important environmental, social, economic and political factors. In essence, a management plan will be recommended, describing the Nations' estuaries and proposing a management system of authorities and responsibilities for their wise use and development.

Now, this ambitious task, of course, cannot be done in any single Federal office. Its success requires that we seek help, advice and the counsel of others. Each Federal agency involved in estuarine work is providing us with detailed descriptions and comments. Likewise, each State is providing similar descriptions and comments.

For those aspects of the study requiring special competence and staff not available within the Administration, such as ecology, social and economic values and sedimentation, we are contracting with other agencies and organizations to provide the needed inputs. For example, we have underway at the present time a contract with the Water Resources Research Center here at the University of Hawaii to delineate pollution problems in estuaries throughout the State and to make an intensive study of Kaneohe Bay.

Also, very importantly, we are working closely with the coastal States. Here, we are working with the State of Hawaii. Through the cooperation and assistance of Dr. Quisenberry, Director, Hawaii State Department of Health and Mr. Shinji Soneda, Executive Officer, Environmental Health Division, we have already contacted other state agencies and have obtained a consolidated description of Hawaii's programs related to estuary management and development. An additional part of their support is the co-sponsorship of today's meeting.

This meeting provides an opportunity that should not go unheeded. Congress has asked for a recommendation before it legislates and it is important that your views be made known. Thank you.

MR. CHAIRMAN: Let me make a few last remarks on the procedure before we begin. With the assistance of Mr. Soneda's office over five hundred invitations have been sent to organizations, agencies, industrial and agricultural concerns, and individuals we thought might have an interest.

However, this is a public meeting and we welcome statements from anyone wishing to speak. If you have not done so already, please indicate on the registration card, which is available at the entrance, your desire to make a statement.

We have made arrangements to reconvene this meeting this evening to receive statements at approximately 7:30 P.M. If the volume of presentations warrants, we are prepared to reconvene again tomorrow morning starting at 9:00 A.M. If you have any questions on making your statement, please ask Mr. I. Terzich, who is standing in back, our Public Information Officer of the Pacific Southwest Region. He is at the registration table there to help you.

Those of you wishing to submit written statements, either now or in the next few weeks are welcome to do so. Mr. Terzich, again, will take them or tell you where to mail them. Any written statements submitted by

February 17, 1969 will be included in the printed record. We have already received written statements from several people to be included in the record.

We have available for those who are going to speak a 35 millimeter projector if they need this. The proceedings are being recorded, and a verbatim transcript is being made, which will provide a complete record of what is said here. We will make copies of it available to the State Department of Health, Hawaii's Official Water Pollution Control Agency.

We have found that generally it is best for the people who wish transcripts should request them through their State agencies rather than directly from the Federal Government. This maintains a normal relationship with the people of the State. However, for those of you who would like a copy, please enter your name and address on the list, which is maintained in the back for this purpose.

If you are planning to speak and have a written copy or outline, it would greatly aid us if you would provide Mr. Terzich with a copy before you begin your statement. Also, if you have any exhibits or any maps to put in, remember that when the transcript is printed, it is printed in black and white. It would help if everyone using visual aids, will try to remember that the statement will appear in transcript form, and avoid saying something like "over there" or "the spot marked in red". It is going to come out in black and white and people will not understand what your reference was.

People who are making statements should come to the lectern in front and introduce themselves. Once again let me emphasize that we are not prepared to entertain questions from the floor. Our purpose is to collect your views and ideas, and not to provide a forum for debate. At this point, might I ask are there any representatives, members of Congress present? Are there any members or representatives of the State Legislature present? Dr. Quisenberry?

DR. QUISENBERRY: I recognize Tennyson Lum of the State House of Representatives. I wondered if Representative Lum would stand? Would you like to make a statement?

MR. LUM: I came to listen.

MR. CHAIRMAN: Thank you. Well first on the agenda I have a card here from Dr. Kenneth Norris of the Oceanic Institute who indicates he wishes to make a statement.

Dr. Norris? Please introduce yourself and your affiliation before your statement.

DR. NORRIS: I am Dr. Kenneth Norris, Director of the Oceanic Institute at Makapuu Point, Waimanalo, Hawaii. And I am here to discuss our interest in the study of pollution in Hawaii. Our interests lie in the importance of surface film in the studies of estuarine pollution. One of the greatest desiderata in pollution work is to develop reliable, specific, and sensitive indices of estuarine pollution.

Another is to understand the biological degradation of films and oil spills. We contend at the Oceanic Institute that the sea surface ecosystem is the key locus for such basic research, because it is a concentrator of pollution by as much as a thousand fold compared to the waters just beneath it. We also contend that Hawaii is one of the best loci in the United States for such work. The study of this film which may be as little as 60 microns in thickness has previously been unavailable for study.

We have developed methods which allow detailed work of this area and have begun a private project funded in-house. This consists of the use of a device called a skimmer which lets us actually roll up the sea surface and collect it in gallon lots for further study. We have developed also methods for the handling of the fragile organisms in this sea surface ecosystem where they are studied in their living form and their culture. From this we projected the plans for the future on the intensification of this program.

Hawaii is ideal for this kind of a study as her waters range from the heavily polluted estuarine waters to the cleanest sea water available anywhere in the central Pacific area since this has no continental land mass. We feel that we may, by the study of this ecosystem be able to trace the course of pollutents out into the open ocean for long distances. And we hope to make contributions in this way to the solution of estuarine pollution problems. Thank you.

WRITTEN STATEMENT SUBMITTED BY DR. NORRIS

What should Hawaii's part be in the national effort to control the pollution of estuarine waters? This question is central to the meeting held here today. I think there are three major answers that need to be discussed. First, pollution in Hawaii is, in important ways, unlike that found in any other state. Second, Hawaii forms a natural laboratory of special value for pollution studies, and third, the State has serious and unique pollution problems that must be studied and solved. I would like to say a few words about each of these statements.

First, Hawaii is the only tropical State, and the only one whose waters are truly oceanic. Her fauna and flora stem from the great Indo-Pacific assemblage of plants and animals, a group strikingly separate from the biota of any other State. This means that the ecosystems into which pollutants enter are likewise different and their effects can be expected to be different. Research that may apply to both coasts of continental United States will not necessarily answer questions for Hawaii. For instance, coral reefs are very sensitive to siltation which chokes the tiny coral organisms much faster than most other marine communities. Sugar cane waste is an important pollutant in Hawaii and is absent as a mainland problem, and so on. The nearly tropical temperatures in Hawaii lead to a new situation when compared to mainland pollution because of the basic differences between temperate and tropical biota and reaction rates. Catastrophic, sudden blooms of plant and animal organisms as well as bacteria can be expected to follow different courses in regard to development times and intensities in tropical water than in temperate water (affected by temperature, length of day, prevailing winds, composition of "starting" populations and water quality). We really cannot yet predict the details of what will happen here (although generalities have long been common knowledge). A systematic study will allow us to handle the complexities. Thus, Federal contracting agencies may expect that it will be necessary to duplicate research efforts in some cases between Hawaii and the mainland.

Second, the uniqueness of Hawaii as a natural laboratory has been emphasized earlier by both Dr. Harvey and me. The unique combination of a truly clean baseline of oceanic water combined with heavily polluted estuaries provides the worker with unusual analytic power. I would like to emphasize at this point that as pollution science has grown more sophisiticated, it has become increasingly obvious that simple indices of pollution such as _E. coli_ counts no longer suffice to describe the amount of many kinds of pollution. Instead, we know we must look into the ecosystem to see how this immensely complicated interacting system has been affected by human intervention. We must be prepared to understand the basic features of the natural food web, the cyclic changes of physical environmental factors, and the progression of man-induced reductions and increases in organisms making up these ecosystems. Fertilization of the sea may wreak changes as important as the introduction of lethal factors. We must look deeply at the estuarine community; the superficial glance of the past will no longer do when we must deal with radioactivity, trace elements and the like. Such refined observations require sophisticated basic research rather than simple "cookbook" studies.

Thirdly, Hawaii, like every other maritime state depends heavily upon its sea. In fact, with tourism rapidly assuming the role of the State's number one industry, a clean environment is essential to economic health. Hawaii's economic baseline is narrow and the seashore is crucial to its stability. The shore must not be only modestly clean; it must be sparklingly clean. The Federal Water Pollution Control Administration should help us achieve that aim.

MR. CHAIRMAN: Thank you. I have a note here that L. Stephen Lau would like to make a statement from the Water Resources Research Center of the University of Hawaii. Mr. Lau?

MR. LAU: I am L. Stephen Lau, Associate Director, Water Resources Research Center, University of Hawaii, presenting orally a summary of a written statement submitted by the Center for this hearing.

In the 1966-67 hearings on Standards of Water Quality in Hawaii, the Center supported the adoption of standards as applied to the estuarine water as well as other waters of the State, recognizing the multiple use of the estuaries and the effects of present and future land uses on their pollution.

Since June 1968, the Center with the cooperation of other University units has been involved in a study of pollution of estuaries in the State under an FWPCA research contract. The results of the first six-months of work are summarized in an 85-page progress report, a copy of which accompanies our statement. This study has two parts:

MR. CHAIRMAN: Excuse me Mr. Lau, do you want that report to be made part of the written record?

MR. LAU:Yes.

MR. CHAIRMAN: O.K. Thank you.

MR. LAU: (continuing) This study has two parts: 1) an extensive survey of the problems of pollution of estuaries throughout the State; and 2) An intensive study of the ecology, the sources and extend of pollution, and the economic implications of water quality standards at Kaneohe Bay, Oahu.

Although the collection of data in the Statewide survey is still incomplete, it appears that there is, in fact, very little factual information on levels of present pollution of any sort, bacteriological, chemical, or sedimentary, and no significant analysis of consequences or trends. Our progress report discusses pollution and pollution problems anticipated on the basis of the estuary uses and of land uses on the estuary shores and in the tributary drainage areas.

The Kaneohe Bay studies involve field collection of basic data in trophicdynamics, sedimentation, bacterial pollution, mineralization of nutrients, photosynthetic activity, and water quality of the bay water. These data will be interpretated in terms of the ecology of the bay and the values of various estuarine uses as opposed to the costs of controlling pollution.

In response to the specific questions raised in quidelines for this hearing:

1) We believe that, except for the commercial harbor uses of some estuaries, the values of estuaries in Hawaii can at present be estimated only very poorly.

2) Our present evidence suggests that, as yet, there has been little damage by pollution to the major values of most estuaries. Esthetic values and certain recreational values have been severely damaged in certain harbors. The pollution of Hilo Harbor has probably been decreased by the construction of a sewage treatment plant and offshore outfall.

3) and 4) It is clear that in a State relying increasingly on tourism, the recreational and esthetic uses of our coastal zones, including estuaries will be increased. Bait fishing will be continued. The ocean will, however, continue to remain our major sink for the disposal of wastes. Commercial harbors must continue to be necessary.

5) It is clear that all three levels of government, Federal, State, and local, need to be concerned with estuary management.

STATEMENT

SUBMITTED
by
WATER RESOURCES RESEARCH CENTER

The Water Resources Research Center has the two primary objectives: To assist in providing the necessary continuously expanding body of knowledge of the water resources of Hawaii and to assist in training water scientists and engineers. It has a multi-disciplinary professional staff drawing on the resources of the University. The concern of the Center is not merely with hydrology but with the engineering, ecological, and socio-political aspects of water as well. Marine waters are of concern to the Center insofar as they are affected by pollution.

At the first public hearing on Standards of Water Quality for Oahu's Waters conducted September 27, 1966 by the Department of Health, State of Hawaii, the Center presented a written statement supporting the establishment of Hawaii Water Quality Standards. In that statement we recognized the multiple use of the estuarine waters of the State and the effects of present and future land uses on the pollution of those waters. Because of the gross inadequacy of knowledge of water quality and ecological effects, we cautioned that the standards initially adopted should be regarded as subject to subsequent review. We recommended investigations of: 1)Urban effects on streamwater runoff; 2) Socio-economic aspects of the beneficial uses of coastal water; 3) Coastal current and hydrography; 4) Dispersion in coastal water; 5) Natural assimilative capability of coastal water; and 6) Baseline quality of coastal water.

Since June 1968, the Center has been involved in a one-year study of pollution of estuaries in the State of Hawaii for the Federal Water Pollution Control Administration under a research contract through the Office of Estuarine Studies. This study is being conducted in cooperation with the Hawaii Institute of Marine Biology, the School of Public Health, and the Departments of Agricultural Economics, Geosciences, Microbiology, and Oceanography. The results of the first six-months of work are summarized in an 85-page progress report, a copy of which accompanies this statement. (Estuarine Pollution in the State of Hawaii, WRRC, Tech. Mem. Rept. 15, December, 1968). This study has two parts: 1) An extensive survey of the problems of pollution in estuaries throughout the state; and 2) An intensive study of the ecology, the sources and extent of pollution, and the economic implications of water quality-standards at Kaneohe Bay, Oahu.

The state-wide survey involves the collection of all available information bearing on the present pollution of the estuaries, the sources of pollution, the ecological and economic consequences of the pollution, and present and probably future trends. Although the collection of data is still incomplete, it appears that there is, in fact, very little factual information on levels of present pollution of any sort, bacteriological, chemical, or sedimentary, and no significant analysis of consequences or trends. Our progress report summarizes what information has been collected for a few major estuaries, and for most estuaries discusses pollution and pollution problems anticipated on the basis of the estuary uses and of land uses on the estuary shores and in the tributary drainage areas.

The Kaneohe Bay studies involve field collection of basic data in trophicdynamics, sedimentation, bacterial pollution, mineralization of nutrients, photosynthetic activity, and water quality of the bay water. These data will be interpretated in terms of the total ecology of the Bay. A socio-economic study is aimed to determine the value of various estuarine uses as opposed to the costs of controlling pollution adequately to permit these uses to continue. Alternate methods for handling expected levels of sewage discharge and streamwater runoff will be considered and, to the extent possible, costs for control will be determined..

A 14-page bibliography pertinent to estuarine pollution in Hawaii is included in the progress report.

The final report of our study will be submitted in about six months. We have recognized from its beginning that a year was inadequate to permit full analysis of the complex ecological and socio-economic implications of pollution even in Kaneohe Bay where our most intensive efforts are applied. However, we expect the results will provide a satisfactory basis for initial managerial decisions used point the way to the more definitive studies required as a more lasting basis for management.

In response to the specific questions raised in guidelines for this hearing:

1) We believe that, except for the commercial harbor uses of some estuaries, the values of estuaries in Hawaii can at present be estimated only very poorly. We hope, however, to be able to make a reasonable estimate for Kaneohe Bay in the course of our present study, and thereby to indicate a methodology for such estimation for other estuaries.

2) Our present evidence suggests that, as

yet, there has been little damage by pollution to the major values of most estuaries. Esthetic values and certain recreational values have been severely damaged in such military and commercial harbors as Pearl Harbor and Honolulu (including Keehi Lagoon). Certain values of Kaneohe Bay have not yet been damaged, but the ecology is so complex, the extent of damage is not certain. So far as sanitary quality is concerned, Hilo Harbor has probably been improved in the last two years by the construction of a sewage treatment plant and offshore outfall.

3) and 4) It is clear that in a State relying increasingly on tourism, the recreational and esthetic uses of our coastal zones, including estuaries will be increased. The tuna industry will continue to require estuarine bait fisheries. The ocean will, however,continue to remain our major sink for the disposal of wastes. Commercial harbors must continue to be necessary. The optimum combinations of commercial, recreational, and esthetic uses will vary from area to area. Such combinations will require skillful management based on sound knowledge.

5) It is clear that all three levels of government need to be concerned with estuary management. The present level of interest of Federal, State, and local agencies with the present and potential problems of estuarine pollution is so recent that it is not clear which combination of agencies can best bring together the concerns with local needs in all their variety,the requisite investigative capabilities, and the regulatory strengths for optimum management.

MR. CHAIRMAN: Thank you. In your statement you essentially have raised several questions. I wonder, does the Water Resources Research Center see need for further research and if so, in what general areas?

MR. LAU: Those points were not questions that we raised. Those points were an attempt to answer some of the initial questions raised in the announcement of the hearing.

MR. CHAIRMAN: Do you see need for further research?

MR. LAU: Oh, definitely we do.

MR. CHAIRMAN: Do you have any specific recommendations to areas of research that ought to be pursued?

MR. LAU: I think this will be delineated in our report.

MR. CHAIRMAN: Thank you. Our next speaker is Dr. Philip Helfrich, of the Hawaii Institute of Marine Biology of the University of Hawaii.

DR. HELFRICH: I am Philip Helfrich, Associate Director, Hawaii Institute of Marine Biology. The Hawaii Institute of Marine Biology has fully concurred with the statement presented by the Water Resources Research Center of the University of Hawaii. There are several points that we wish to make in addition to those expressed by Dr. Lau.

The cost of this pollution and the effects on the environment are often difficult to ascertain, mostly because of our poor knowledge of the complex environment and lack of baseline data from which to work. Further, the adverse effects of pollution may reach unmanageable proportions before control can be applied. I think it is safe to say that most of our citizens subscribe to the general concepts of conservation of our natural resources and preservation of the natural beauty of Hawaii. But, if individuals, those who have vested interests will be more strongly motivated than society as a whole.

Thus, the developer clearing shoreside land and the engineer planning a sewage treatment plant, or the citizen faced with a tax assessment have a stronger personal compulsion to act in a way that may be detrimental to the maintenance of high standards of water quality in a given body of water. Because of his--his personal success and his resources and possibly his welfare are involved in his project or role, it is only natural that the developer, the planner, and the tax payer will rationalize that his actions are really not significant in the overall conservation picture. If indeed, he has given the conservation aspect any serious thought at all.

Thus, the decisions and actions of individuals with the special interests relating to the assigned tasks or personal profit will not be in the best interests of society in the matter of conservation.

Hereafter, my reference to special interests will refer to those persons whose object is to carry out the assigned tasks or for personal profit. Individuals with such special interest do not intend to deteriorate the environment, they may only be a passing by-product of their particular endeavor; thus the developers are concentrating on building homes and they may not be aware of the poor soil conservation practices or the effect of the siltation and runoff in the nearby waters.

We do often feel that we are protected from those who pollute, and this is particularly true since the FWPCA water quality standards were adopted by the State of Hawaii, but the best laws are not all inclusive. And they are only effective if the enforcing agency has been properly administering them. Most often enforcement follows a flagrant violation and a public outcry.

All of this points to the need for greater diligence and concerted efforts on the part of conservation minded citizens to maintain high standards of water quality for our coastal water estuaries.

The best use of our estuaries vary depending on the body of water and those involved in the determination. Generally, those who live adjacent to or near a bay or estuary, are possibly less suited to determine the best use of that body of water. But often there is a disagreement on the best use of an estuary, a situation that might be advantageous to the person with special interests.

In addition our system of government tends to favor the special interest and make it difficult for an individual citizen to be effective against special interest groups. Based upon the above general statement and with Kaneohe Bay in mind, the following recommendations are made: That a water use committee be established for each of the major estuarine bodies of water in the State of Hawaii, with a function comparable to the State Land Use Commission.

This committee should include representatives of all interested parties. Those that are contributing to the determination of the body of water, and those interested in the conservation of its desirable attributes. Thus, in the case of Kaneohe Bay, this committee should have such representatives as the Kaneohe Bay Yacht Club, the City and County Sewer Department, and the U. S. Marine Corps, the Board of Parks, and Recreation, the University Research Laboratory and so forth.

This committee should formulate a plan for the best uses for the various part of the body of water, and advise the appropriate agencies of the plan and act as a group to carry out continuing surveillance on the development of this plan. Communication between the special interest groups would thereby be implemented.

It is further recommended that this committee review the existing legislation relative to their body of water to ensure that the laws are appropriate and can be enforced and to make recommendations for revision of these laws if necessary.

We feel that Kaneohe Bay is the finest body of water in the State of Hawaii from the standpoint of recreation , resource of bait fish. It is our considered opinion that implementation of the above recommendations would favor such use and make this a high quality--water quality standard.

MR. CHAIRMAN: Thank you, Dr. Helfrich. The next speaker on the agenda is Mr. Francis Lum, of the USDA Soil Conservation Service.

MR. LUM: Ladies and gentlemen. My name is Francis Lum. I am going to read a statement submitted by Fred Haughton, Jr., State Conservationist.

About thirty years ago when the first soil conservationist of the U.S. Department of Agriculture's Soil Conservation Service arrived in Hawaii, I'm sure he took careful stock of the pollution of our estuarine areas. He probably went out after the first rainstorms and noted all the coastal areas tinged red with sediment. Back then, he proabaly wasn't as concerned about the polluted coastal waters as our conservationists of today would be.

The early conservationist had come to work with the agricultural interests in helping to control accelerated soil erosion. He looked at the sediment polluting some of our estuarine areas as the symptom of faulty land use practices in the watershed above. He knew that the pineapple planted in rows up and down hill rather than across the slope wouldn't help to hold the soil in the fields. He saw that the close grazing by cattle on dryer grassland would create the same erosion problems they were combatting back on the mainland.

Having located the lands which were in need of conservation treatment, our conservationist thenceforth paid scant attention to the shoreline areas which, after all, were outside of his kuleana.

Today, technicians in the Soil Conservation Service look on the estuarine areas in a different light. Broadened responsibilities in areas such as providing assistance in development of flood control, irrigation, recreation, fish and wildlife and other projects often focuses on the estuary system as the benefiting areas. SCS soil scientists in mapping and describing the soils of the State under the National Cooperative Soil Survey program have helped develop an insight on the technical nature and process in which thousands of acres of offshore waters can turn red after storms.

Along the southern coast of Molokai from Hale O Lono point to the vicinity of Wailua, a distance of some 33 miles, there is an almost continuous shoreline of soil deposition--the local people call it the mud flat. At low tide, one can virtually walk out to the reef that borders the coast. This deposition is the result of silt-laden, swift flowing storm waters which have released their soil loads upon reaching the flat shorelines. Where there existed 58 rock-walled fishponds built by the early Hawaiians, today only four remain in commercial production. Records show that extensive use and maintenance of most of the ponds abruptly ended during the early 1800's. This was the period after the introduction of grazing animals onto the uplands and the beginning of silt-laden stormwater flows resulting from the over-grazing of the land. What had taken the early Hawaiians about a thousand years to build was rendered useless in a fraction of that time.

Yesterday, the anthropologist, the historian, and the 'fish-farmer' himself, were the only ones really rueful of the destruction of what was an important part of the early Hawaiians source of food and income. Today, others have become concerned. The oceanographic researcher needs the ponds for his work. The resort developer needs a clean shoreline and clear offshore waters for the tourists to recreate in.

About two years ago, SCS technicians investigated storm damages which occurred at Napili Bay, a resort area on the west coast of Maui. It was their third major storm in a six-year period. Interviewing resort hotel managers, it was found that the hotels suffered damages amounting to $143,000 of which $41,000 was attributable to sediment. About $5,000 was spent just to publicize to prospective guests that the hotels would still be open for business. Even then, many guests with reservations never checked in. And those that did show up cut their stay shorter than planned after seeing the red stain of the bays swimming waters.

In this same area, on the upland pineapple fields, measurable agricultural losses amounted to $35,000. The value of the soil that was lost, including the fertilizer and other elements on which profitable production of the crops are dependent, couldn't be measured at that time.

Right after that storm, plantation officials asked the Soil Conservation Service technicians to aid in developing a plan to minimize the erosion of the fields and reduce the sediment entering the bay. The fields were relaid on the contour of the land, with roads across the slope adapted as diversion ditches. The ditches were laid out to carry runoff waters to a nearby gulch. A desilting basin was laid out at the end of the gulch to further control the sediment. Since the new layout was installed, several storms have occurred to test its effectiveness, all with gratifying results. The hotel managers state that where the swimming waters used to take weeks to clarify, swimming is now back to normal in a few days.

We can recognize that sediment resulting from erosion is assuming an increased importance in our society. Hawaii's economic expansion, based largely on the resort industry, can be stifled without control of the sediment polluting our offshore waters. Controls are needed not only for the natural storm runoff but also for the silt introduced via sugar mill wash waters and irrigation tail waters. The subdivision developers must comply with soil and wind erosion practices, much of which are already specified in County grading ordinances. There is no longer a distinction between agricultural and urban use and management of our soil resources as far as their effects are concerned. Everyone benefits from good agricultural crop yields, unpolluted waters for good fishing and swimming, and longer tourist stays which will result from the prevention of sediment pollution of our estuarine waters.

There now exists a distinct need for economists and planners to evaluate in monetary terms the losses accruing from sediment pollution of our estuaries. The SCS, in preliminary findings on the effect of stained offshore waters on the value of resort-zoned lands, has found that the market value of these lands are depressed by about $1.00 per square foot. More work is certainly needed in this area. We need to evaluate losses, such as that accompanying loss of topsoil, from having to remove sediment from harbors, canals, channels, ditches and recreational areas, from increased flood occurrence due to sediment encroachment of flood channel capacities, from decreased storage in reservoirs, from damage to plant and marine life by sediment and from decreased recreation and esthetic values.

The soil scientist now has provided the land use planner extensive data on his land. For example, he can locate the areas with soil developed from volcanic ash. He will probably determine that this soil will be suited for pasture use, and with irrigation excellent for vegetable fruit and nut crops; because of their good drainage, high bearing strength, favorable topography and freedom from flooding, these soils are well-suited for urban development. He will also warn that though these soils are easy to work, they have a tendency to be powdery and structureless and are highly susceptible to both wind and water erosion unless carefully managed.

With this type of information, the landowner and the planning conservationist can begin the planning process whereby accelerated soil erosion will be minimized and our estuarine areas can eventually approach returning to the state nature had intended. Thank you.

MR. CHAIRMAN: Thank you. Any questions? I think at this point, if we can, we will recess for about fifteen minutes. There is coffee on the table there, if everyone will help himself. Thank you.

RECESS

MR. CHAIRMAN: If we can reconvene, please. The next statement is from Dr. George Harvey of the Oceanic Institute. Dr. Harvey?

DR. HARVEY: I am Dr. George W. Harvey, Director of the Marine Ecosystem Program of the Oceanic Institute. One thing I would like to say before I go any farther. I would like to say why I am interested in the estuarine problem and why I am out here in Hawaii. Earlier I worked about four or five years on a similar problem off the Coast of California.

I found that some of my biggest problems in the scientific work that I was doing arose from the extensive pollution of the sea surface--in the area that I had available.

I came out here to Hawaii, realizing that this was probably the world's best area for the study of Marine Pollution and Estuarine Pollution, because here we have very extensive pollution--a very severe pollution problem. I would like to make out what I have seen so far--at the same time we have very near the island some of the cleanest waters in the world for the work that I would like to do.

Now, the motivation in doing this work probably stems from a desire to do something in the direction of conservation, and when I first saw Hawaii, I found an area that had beautiful unspoiled hills, and green trees growing all over, and the Hawaiian clean waters, beautiful beaches, and one of the most beautiful seashores anyplace in the world. These things look fine to a tourist or newcomer, but there is a very definite advantage to this.

These represent resources of great financial value to the whole community. And, of course, in other ways as well. Now, the clean waters--everyone knows why we need it. The unspoiled beaches are necessary for the maintenance of marine life that have lived here for so very, very long. And, of course, our estuaries and bays are needed for everything from fishing, shipping on to the maintenance of stocks of certain kinds of fish for the production of our bays. Some of our bays are very great producers of shellfish for local consumption.

Anyway, I would like to see this whole thing go on. As far as the advantages of this area, the advantages possessed in the past--we have lost some of the most valuable estuarine areas. There is a place, there in Hawaii Kai, and one over there in Enchanted Lake; these used to produce quite a large amount of fish for people who lived in the area. These things will never be available again in the same sense that they used to be. They are now serving other purposes.

When I first took a look at the water in Kaneohe Bay, I found that there was a difference from any water I had looked at yet, in some respects, and in others it resembled the waters in California, the sewage outflow with certain very large amounts of organic material. In Kaneohe, I haven't looked at very many samples, but the ones I have, there are a remarkably high number of bacteria. I don't know the species, but I can say it is a typical marine bacterium. There are others associated with these that are probably not typically marine bacteria. There are various flagellates that enter into this whole microbiological system. Associated flagellates are very difficult to preserve and find by ordinary methods. And they remind me very much of the working conditions off the coast of California.

I think that in studying the microbiological picture in Kaneohe Bay we are going to have to have a lot more activity there. I can understand that this will be probably under the direction of the University of Hawaii, that will be better suited for looking into this type of organism, and so on.

I know very little about that part of the picture. But I do know that there is a very large amount of what is probably ordinary polluting material there. Probably material that is not representative of the same that you have in Pearl Harbor. The problem that you have there is from sewage runoff and soil runoff, and you will have a good deal of material produced by the ships that are anchored, and that makes it a little more complex than in Kaneohe Bay.

Now, this is the picture that I get without very much study. I think that Bay is perhaps one of the very finest laboratory situations in the study of estuarine pollution where you have a large concentration of material at one end and at the other area a circulation of sea water, the concentration obviously is a good deal less. The Oceanic Institute has a program that is financed by our own sources and this is directed to what we think is the most important point of the study of the pollution picture here in Hawaii.

We have ideas that we are doing on the future of similar areas. Similar to the areas in California. Right now we are trying to pinpoint the things that is most urgent. And I think one of the first things is the study of the microbiology of the surface layers. Here we would seem to have a concentration of organisms--well, in all waters we would have a very rapid turnover of the organisms, so that you are familiar with the life cycles, in terms of hours instead of days, and so on the scale. The larger organisms take more time.

One thing that seems very different to me here than anything that I have seen in temperate waters, and I have studied clean water in lower California so I have something on which to base this comparison. The warm temperature seems to produce a greater number of species and fewer organisms. Now, this is a very well known phenomenon in marine biology. The warmer the water, the greater number of species and the greater kinds of organisms, the fewer we find in the rest of the population. The population is very, very mixed. You have everything from bacteria to larger flagellates. You have many species of each one of these types of organisms.

Now, there is one problem that has never been answered to my satisfaction in Marine Biology. The problem of metabolic rates of the life cycles of the typical micro-organisms that live in the upper layers of the sea shore. These things have been studied to some extent, but never fully enough to answer the question. I think the question may be of practical importance right now in the Hawaiian area, mainly because of the fact that we find so many organisms and we now know so very little about the rate of turnover. In other words, we honestly don't know very much about the metabolic rate of the sea water itself.

In other words, what is the rate at which oil particles of a certain size may be broken down and converted into the living organic material. The marine bacteria take care of almost all of the oil in the form of conversion. Now, we don't know whether we can take care of it now--we doubt we can take care of it because of the Hawaiian concentration along the shore. We may see an increase in the build up of the concentrated oil that we had a few years ago.

So we need definitely to know more about the rate of turnover, not only in oil particles, but in carbohydrate material and even cellulose material. The only thing that is quite obscure at the present time is that we honestly don't know what kind of organisms are involved. It is very easy to say that bacteria takes care of the whole thing, but actually, as near as I can tell so far, the bacteria don't play necessarily the major part in the degradation of the organic material in the sea. They may play a minor part in some cases, but we don't know what this part is.

For instance, in addition to many bacteria that I have seen alive that have a very rapid motion as you observe them in while they are in degradation. Some of these were in microforms of very fine flagellates and amebas that take care of it. We have seen them with our own eyes under the microscope. They can take care of material that is supposed to be handled by bacteria. I would like to study more of these micro-flagellates and understand--they start with the raw material that they have available and go right on down through the changes.

We know isolated parts of the picture. We know that some organic material is broken down to inorganic groups. These small organisms are broken down and we see this over and over again.

We see things like this. Some appearance of a particularly unknown micro-organism that has never been reported in literature; we see this appear in large quantities time after time, which is why you just have to learn what it is.

I think that as we learn something at the Oceanic Institute, the people at the University of Hawaii would like to contribute to the practical application of this knowledge.

THE IMPORTANCE OF SURFACE FILM STUDIES TO ESTUARINE POLLUTION RESEARCH

submitted by
Dr. George W. Harvey, Director
Marine Ecosystem Program
Oceanic Institute

One of the major problems in the study of estuarine pollution is the development of reliable indices for the kind and amount of pollutants. In all aquatic environments a few loci are most promising for such development. We contend that detailed study of the ecosystem found in the surface film has the best chance of providing such indices, because many pollutants are concentrated there. Such concentration occurs at the sea surface as a result of their physical and chemical properties, and because of certain processes in the sea. Very small quantities of some of these materials as well as natural products from marine organisms exert profound effects on the surface layers, especially at the boundary represented by the air-sea interface. The sea surface is an unknown region because until recently it has not been available for study.

Beginning in 1963, a long-term study of this region was begun on an ASW oriented program. Because no effective methods then existed, new ones were developed and studies of surface water were initiated. The most laborious and expensive part of this work having been completed, there are now available equipment and methods (large, small and micro-skimmers, plankton siphons, micro-physical oceanographic methods, and nannoplankton methods) for continuing studies of the sea surface, and for the direction of such studies at estuarine pollution problems.

The studies of the properties of the upper 60 microns have shown that this layer contains a heretofore completely unexplored ecological niche. The implications discovered were unexpectedly far-reaching. Concentration factors for living and inorganic particulate material and for other organic material were typically 3 to 1,000 or more times greater than in the immediate underlying water. Some of the organic materials were film-formers that very greatly altered small scale turbulence, wind-induced currents, temperatures, gas exchange and distribution of bacteria and micro-flagellates.

Large numbers of several apparently undescribed species of micro-organisms that very likely are important in the metabolism of oil films and other organic material near the surface have been found. The lead content of the surface layer along the California coast is markedly increased, probably from fallout of automobile exhaust emission. Quantities of inorganic carbon found in this layer may originate from jet airplane exhausts.

Large numbers of "sewage" organisms probably are maintained by the sewer outfalls along this same coast. The ecological balance of this water layer may be shifted by varying quantities of toxic industrial waste materials. Although we now have some evidence regarding the above materials, the latter have not yet been measured, nor has the concentration of radioactive materials been determined except for some preliminary low-level work by T. R. Folsom at Scripps Institution of Oceanography, La Jolla.

Uncontaminated sea water surface samples could not be provided in the Southern California region without serious degradation due to the long shipping distance (50 to 300 miles). Clean water, but no laboratory facilities, was available near San Quintin Bay, Lower California. Thus, comparisons based on uniform clean water were difficult to secure.

The sea surface study soon showed that much remains to be learned about the surface layer in areas near large human populations, before indices can be developed.

This study program, begun in Southern California, is continuing at Oceanic Institute, Makapuu Oceanic Center, Hawaii. Here there are far better conditions for a coherent study because of a nearly ideal range of conditions varying from very clean mid-ocean sea surfaces to heavily polluted estuarine water. Dependable, sophisticated laboratory facilities and analytical equipment are available, backed by a competent instrumentation laboratory.

This work is now being carried on with modest in-house support at Oceanic Institute, with the immediate aims necessarily narrowed to the following:

1. Sampling of surface water in two dissimilar areas of Kaneohe Bay, and off Makapuu Point, plus occasional samples from other areas.

2. Occasional sampling from areas characteristically covered by oil.

3. Direct observation of undegraded samples for quantitiative and qualitiative study of bacteria, microflagellates and other very small organisms.

We wish to extend this work in the following directions in the near future, as soon as additional funding is developed:

1. Culture of key organisms for identifications and determination of ecological niche.

2. Culture and handling of organisms that could be used for oil control in areas of chronic spillage.

3. Determination of relative chlorophyll, protein and turbidity by means of direct fluorometric methods.

4. Determination of characteristic trace elements after preliminary qualitative tests, using the atomic absorption spectrophotometer.

5. Measurements of near-surface windspeed and surface temperature at place of sampling.

6. Salinity measurements of typical samples.

7. Spectrophotometric determination of materials extractable directly from the sea water samples^ using the recording spectrophotometer.

We contemplate studies beyond our present instrumental and manpower capabilities including:

1. The concentration of particulate material from the surface film by use of the density gradient centrifuge, for more refined quantitative study of such particles.

2. Concentration factors for radioactivity and occurrence of pesticides in the surface film.

3. Use of synoptic data system and computer techniques for correlation of physical variables and sea surface samples.

The approach in this work is directed toward some of the targets that we think should be given a high priority in studies of estuarine pollution. It is hoped that as we learn more about the ecological realtionships, of which so little is how known, in the surface layers of the sea, this knowledge will find early application.

MR. CHAIRMAN: In view of some of the remarks that Dr. Harvey made, I wonder if Dr. Helfrich would be available for a couple of questions?

DR. QUISENBERRY: While Dr. Helfrich is coming, Mr. De Falco, I would like to ask him a few questions in view of the remarks made by Dr. Harvey, because I know that Dr. Helfrich and the colleagues we mentioned have studies Kaneohe Bay specially, and I didn't understand from his presentation, perhaps, as much as I should have.

He covered some of the points which I am interested in. One being the effects on the marine life, including fish, of the pollution as you have seen it and as to whether you have been able to identify the specific pollutions and their source in regards to the temperature change involved in some of the effects that you have been there in Kaneohe Bay. Could you elaborate on these points a little bit?

First as to the specific effects on the marine life including fish. Have you been able to show this through studies that you have made?

DR. HELFRICH: I am a little reluctant to make at this time a statement because one, I am not fully aware of all the research that is presently going on in the State. I am aware, of course, of what Dr. Lau has reported on but there is nothing specific on fish. I think that possibly some of the confusion that was made might be because the group is concerned primarily with bacteria associated with sewage. These areas do overlap, but the initial results of Dr. Gunderson's study did indicate that the major source of bacteria related to sewage is from the streams.

And the high counts were up in the streams. And the Bay count was not particularly high.

DR. QUISENBERRY: I think that helps in satisfying one of my questions. Have you any information on the effect of temperature change in Kaneohe Bay? On this marine life.

DR. HELFRICH: Only in that our people have been working with the culture of very delicate--the larva forms of very delicate organisms. The larva forms--they are very sensitive to the temperature changes. I am particularly impressed that the success or failure in culturing a group of these organisms can depend on a number of things, some of which we haven't been able to identify. For instance, such as temperature changes of a rather small degree. In the case I have in mind 1.5 degrees centigrade is enough to cause high mortality in the cultures of marine mollusks.

But I am very reluctant to relate this to what is going on in Kaneohe Bay. It may be that this is a normal sort of thing and that one out of every 10,000 marine mollusks normally don't make it because these changes occur naturally. So that our real difficulty is in relating the experimental work going on in the bay and that is the reason that I think that the estuarine study group--one of its major goals is to try to establish some baseline from which we can see the result of the major changes.

If I can summarize, this may sound familiar to many of you. The environment is extremely complex. I don't feel that any one or two or five year studies are going to give us any major significant answer, but this doesn't mean that we have to throw up our hands and say we can't learn anything from the study of it. It is an extremely complex picture that we are attempting to put together piece by piece., the various disciplines that are--

MR. CHAIRMAN: Doctor, would you say that the state of the art of the estuarine zone is anywhere near the comparable state of the art of the true marine or fresh water forms?

DR. HELFRICH: Well, perhaps not in accomplishments. There are many fine estuarine studies--much of the experimental physiology is more related to the estuarine study than the fresh water. Sanitary and temperature tolerances, interactions, and so forth. We have a long way to go.

MR. CHAIRMAN: Thank you. Although not wishing to make statements, we do have present representatives of many organizations and I would like the record to indicate that the following organizations are among these represented. Outdoor Circle, The Honolulu Garden Club, The Junior League of Honolulu, The Pearl City Community Association, The Dole Company, The Del Monte Corporation, Hawaiian Electric Company, Standard Oil Company, Hawaiian Water Pollution Control Association, Hawaii Society of Professional Engineers.

Do we have any other statement at the present time? Well, if not I would like to recess this for lunch; and we will reconvene at about 2:30. Thank you.

RECESS

P.M. SESSION 2:30 P.M.

MR. CHAIRMAN: Could we reconvene the meeting please? I understand that we have received a communication to be read into the record. Dr. Quisenberry, would you like to--

DR. QUISENBERRY: Thank you. This is a cablegram sent from Washington, D.C., dated January 27; it's addressed to the Honorable John A. Burns, Governor of Hawaii, Iolani Palace, Honolulu, Hawaii, and the message is: "Because of receipt of late notice, I am unable to arrange for other than presentation of a written statement regarding State wide Estuarine Public Meeting, January 28-29, co-sponsored by the State of Hawaii and FWPCA. The question of the nature and the extent of pollution in the nation's estuaries is one of increasing concern to Congress, and the Hawaii meeting will no doubt provide much useful information. Aloha, and Best Wishes, Spark Matsunaga. Representative in Congress from Hawaii."

MR. CHAIRMAN: Thank you, Dr. Quisenberry. I would like to continue reading into the record the names of some of the organizations that are represented here. If I may, the Channel and Harbor Dredging Co., The Maui Pineapple Company, Theo. H. Davies and Co., Ltd., Oahu Sugar

Co., Hutchinson Sugar Co., Ltd., The Hawaiian Sugar Planters Association, The Conservation Council for Hawaii. I would also like to point out that there are a number of representatives of various municipal, county, state, and federal agencies, that are present at either this morning's or this afternoon's meeting. And I will refrain from reading the other agency names into the record other than to indicate that the agencies with interest are present.

Are there any additional statements to be made? I am not aware of any at the present. In view of the lack of statements, I guess we are going to have to recess the meeting until this evening. We hope to reconvene at approximately 7:30 this evening for any additional statements. Thank you very much.

7:30 P.M.

MR. CHAIRMAN: We will reconvene the meeting on National Estuary Studies. I have here one additional request to make a statement. Mr. Scott Hamilton, President of the Conservation Council of Hawaii. Mr. Hamilton.

MR. HAMILTON: Mr. Chairman, distinguished guests and members of the audience, I have already distributed a statement and supplementary sheet to the individuals and to the secretary. If there are any additional copies requested, I would like to present them to you.

Before beginning my remarks I should like to joke with you just a little bit about the difficulty of coming in from Pearl Harbor. It seems that my Admirals have a certain precedence over my schedule and they are more interested in salt water than what happens to pure water. This may account for my delay in getting here. The second thing that I would like to add is that some of our secretaries have a degree of difficulty in understanding what estuarine stands for. It seems that my secretary thought that it was some sort of a sex hormone. And I had to have her spell it before I realized what she was truly talking about.

The third humorous remark is that I made a cursory examination of similar conservation groups over the dinner period and found out that a number of them would like to make testimony but they had not been duly notified, and I made the mistake of calling the Conservation Chairman of the Hawaii Trail and Mountain Club out of the bathtub in order to discuss the estuarine conference with him; and he said rather blandly, "Well, I am really not in much position right now. We will discuss the remarks later." He was enjoying, I am sure, the purity of the water in his bathtub at the time that I called.

I represent the Conservation Council of Hawaii, and I appreciate this chance of giving brief testimony, very brief on short notice in order that we might at a later date, when our Board convenes, give you something much more specific.

Since its inception in 1950 following the Pacific Science Congress, this Council has considered the purity of waters and dangers of the water pollution one of its primary concerns. Our testimony is meant to supplement remarks that will be offered by Dr. Stephen Lau of the Water Resources Division, who is Water Chairman of the CCH, by Dr. Doak Cox of that Division, who is a former President of CCH, and the very interesting proposals of Dr. Philip Helfrich, Assoc. Dir. of the Hawaii Institute for Marine Biology, who is one of our Board members. The proposal for Water Use Commissions, similar in approach to the State Land Use Commission, is one which we urge further study upon. The Conservation Council may, after due consideration, be prepared to work actively for its implementation during 1969, but I am not at liberty, without Board approval, owing to the short notice, to give unconditional endorsement.

The Hawaiian Islands has been known for ages and throughout the world for its beautiful environment. The people of Hawaii not only treasure and enjoy the beautiful total resources, including estuarine and coastal waters but share them with visitors with the spirit of aloha. The use of Hawaii's natural resources has created not only stimulus and substance for the tremendous economic growth in recent years, but also a complex urban system in many places on the principal islands. All economic indicators show continued upward trending. In the wake of progress, potential pollution of estuarine waters by both urban and rural systems is a definite threat to the use and enjoyment of these waters and will adversely affect the economic and social well-being of the people of Hawaii,

The Conservation Council of Hawaii represents a group of citizens of Hawaii who promote the principles of conservation and wise use of natural resources. The Council is in full accord with the purpose and scope of the National Estuarine Pollution Study as authorized by the Clean Water Restoration Act of 1966 P.L. 89-753, November 3, 1966, Title II, Section 5 (g) (1).

The Council is cognizant of the governmental agencies having administrative responsibilities and institutions having the capability to conduct investigations and research in estuarine water. However, the Conservation Council of Hawaii wishes it entered in the records that it stands for the conservation and best uses of estuarine waters of Hawaii which will permit their perpetual enjoyment and benefit by residents and visitors alike and further that the Council supports the cooperative endeavor by the State of Hawaii, the University of Hawaii through its several centers of research, and the Federal Water Pollution Control Administration in carrying out the mission of the National Estuarine Pollution Study.

Our Board meeting will probably be held the first week of February, and I dare say that we will have a great deal to furnish at that time. Thank you very much.

MR. CHAIRMAN: Thank you, Mr. Hamilton. Are there any questions? Mr. Hamilton, I would like to reiterate that the record for the meeting will be open until February 17, to submit a written statement. We will be very happy to receive a written statement at that time.

MR. HAMILTON: May I ask one question of you? I would like to indicate that our Council has prepared a Conservation Digest. If your local staff member desires to contact me in order that such a statement might be included, I shall prior to Friday be glad to present him with a copy of the preliminary draft. Had we been contacted in due time, we would have volunteered to telephone the organizations that we thought might have pertinent testimony, because I am sure that we would have had greater participation this evening.

MR. CHAIRMAN: Thank you. Are there any other statements? I think we will recess the meeting until tomorrow morning at 9 A.M. Thank you.

JANUARY 29, 1969

MR. CHAIRMAN: We will reconvene the public meeting on National Estuarine Studies. I have a request for a statement by Mr. Archie Eriksson of the Windward Citizens Planning Conference. Mr. Eriksson?

MR. ERIKSSON: You mentioned statement. I would like to make several if I may. As a member of the Windward Citizens Planning Conference, I am very deeply concerned with our windward side of the islands, particularly from the standpoint of our solid waste as accumulating in such proportion that it is visible from every sidewalk, from every street, from every vacant lot in the community. We are hoping that in a program that we are trying to initiate this year, that adults as well as high school people to see if we can't possibly get our community involved in a process whereby we can help in the soil retention and water retention and beautification of our country side.

We are offering as a proposal or suggestion that a concept, a single concept whereby all solid waste be brought into one area; when we say all waste, we mean automobiles that are abandoned and refrigerators, water heaters, upholstered furniture, dunnage, demolition materials, animal waste, and in so doing pick it over, reuse it wherever we can, and process it so that we can use it as a mulch or in the final stages as an organic soil supplement that can be put back into the soil. The amount that could be accumulated would only be a drop in the bucket as to the amount that would be needed. For instance, Pacific Concrete is now producing sand. And in so doing they will take down all of the coral knoll on the other side and leave the land flat.

Well, that coral underlayment there is not going to be conducive to further planning. We are suggesting that if we could have approval by City officials whereby we could put in a one hundred ton a day plan, utilize all this material, then we could mix it with the heavy soil and come back and put in a 10 inch coating mulch in the soil and reactivate the soil and return it to the Hawaiian Homestead Act as good real estate.

Also, in the area where tilthing is being done, just opposite the YWCA, I wouldn't be surprised if it would run as high as 30% or more of topsoil. That was washed off in the last heavy rains. We could have saved a great deal if we did have enough basic materials such as rough fibrous material to put on the ground before they start to disperse.

We want to get young people interested in this movement of conservation, preservation, and beautification. We plan this year to plant 10,000 trees for our re-forestation and beautification program. At the same time, develop a fund whereby youth in summertime can get together an hourly employment to earn pin money so that they can go out and pick up litter from the countryside.

This means by which we have for financing that is--we have an area now with 5,000 cubic yards of five-year-old composted animal manure that could be bagged and sold, and the money goes to the student bank.

We propose to get a series of dances that would bring in money and also a junk sale whereby everybody would clean out their attics and garages and the money from that would go into this fund to pay the youngsters an hourly wage to go out on the countryside all summer and pick this material up. This is one of the ways in which we can plan to start young people moving in our program on conservation and beautification.

This is just a suggestion of thought that is occurring in the Windward Citizens Planning Conference. I am the chairman of the Beautification Program, and we feel that we have to start with the soil if we are going to do anything to further develop beautification. I hope this may be of consideration to people who are in government. We are seriously contemplating to see if we can't do something for Windward Hawaii. Thank you very much.

MR. CHAIRMAN: Thank you, Mr. Eriksson. I also have a statement from Mr. Vern E. Cronkhite of the Hawaiian Electric Company.

MR. CRONKHITE: I am Vern Cronkhite, principle design engineer for the Hawaiian Electric Company. The Hawaiian Electric Company is extremely interested in maintaining the quality of Hawaii's coastal waters. In particular the section on standards dealing with thermal pollution is of immediate concern as we of necessity discharge warm water from our generating station.

We have been following closely the government and implementation of the standards. Thus, as a matter of public record, we have been considering a possible site for a new generating station on Kaneohe Bay. As part of our study for this site, we supported the research of the Department of Oceanography at the University to determine the temperature situation in Kaneohe Bay and of possible effects of warm water discharges of bay temperatures.

We have further offered to participate in the support of another research project with the Department of Marine Biology to determine the effects of temperature on marine life. This project is now waiting Federal approval of the plan by Dr. Brock and is entitled, "The Demonstration of the Effects of Thermal Loading on the Hawaiian Marine Biota."

We have been and will continue to work for the State Department of Health, in the Environmental Health Division in the operation of our existing plant and in planning and designing future plants to minimize any serious effects of our warm water discharges on the quality of our coastal waters.

MR. CHAIRMAN: Thank you, Mr. Cronkhite. Are there any additional statements?

I would like to repeat again that the record will be held open until February 17, 1969, for additional statements from those who would like to be on the record. The transcript should be available in approximately three months from this date. I want to thank all those who took the time to come to the meeting. I personally have gained considerable knowledge and a better insight to the problems of the State of Hawaii, particularly its estuarine problems.

I particularly want to thank the State of Hawaii not only for their assistance in putting on this meeting, for the assistance they have provided in preparing a State profile on the State's activities in the estuaries of Hawaii, for their contribution of their fiscal views of what the management programs should consist of and with that I think that we shall call the meeting adjourned. Thank you very much and Aloha.

-oOo-

34-a

STATEMENTS AND REPORTS

FOR THE RECORD

34-b

RICHARD B. RUSSELL, GA., CHAIRMAN
JOHN STENNIS, MISS.
STUART SYMINGTON, MO.
HENRY M. JACKSON, WASH.
SAM J. ERVIN, JR., N.C.
HOWARD W. CANNON, NEV.
ROBERT C. BYRD, W. VA.
STEPHEN M. YOUNG, OHIO
DANIEL K. INOUYE, HAWAII
THOMAS J. MC INTYRE, N.H.
DANIEL B. BREWSTER, MD.
HARRY F. BYRD, JR., VA.
MARGARET CHASE SMITH, MAINE
STROM THURMOND, S.C.
JACK MILLER, IOWA
JOHN G. TOWER, TEX.
JAMES B. PEARSON, KANS.
PETER H. DOMINICK, COLO.
WILLIAM H. DARDEN, CHIEF OF STAFF
CHARLES B. KIRBOW, CHIEF CLERK

United States Senate
COMMITTEE ON ARMED SERVICES
WASHINGTON, D.C. 20510

February 17, 1969

Mr. L. E. DeCamp, Acting Chief
Estuarine and Oceanographic
Programs Branch
Department of the Interior
Washington, D. C.

Dear Mr. DeCamp:

Attached you will find my statement for the record concerning the status of pollution in the Nation's estuaries as mentioned in your letter received January 24.

Sincerely,

Daniel K. Inouye

DANIEL K. INOUYE
United States Senator

DKI:abt

STATEMENT

Recent legislative activity demonstrates a deep Congressional concern over the pollution of our nation's water resources.

This concern comes none too soon if we are to win the constant struggle for the preservation of man's natural environment and secure it against his demonstrated penchant for misuse and destruction. Nowhere is this problem more clearly evident than in our nation's estuaries, which have been the site of so much of man's early and continuous commercial and economic activity.

Because of its geographic characteristics, pollution of the surrounding waters is of particular concern to all who call Hawaii home and to the millions who seek her shores, even if but for a brief respite from their normal place of residence. Rehabilitation is a process demonstrably so difficult that prevention of further pollution must achieve an even higher priority, as we seek to alter the patterns of the past in our quest for a more liveable world.

HAWAii

36

Copy sent to
Mr. Lerzich 2-5-69

TEIT
2/6/69

DEPARTMENT OF PLANNING AND ECONOMIC DEVELOPMENT

426 QUEEN STREET • HONOLULU, HAWAII 96813

STATE OF HAWAII

JOHN A. BURNS
Governor

SHELLEY M. MARK
Director

EDWARD J. GREANEY, JR.
Deputy Director

January 21, 1969

JAN 22 1969

Mr. Donald B.Mausshardt
Federal Water Pollution Control
Administration
Pacific Island Basin Office
Room 426, 1481 South King Street
Honolulu, Hawaii 96814

Dear Mr. Mausshardt:

In response to your invitation, we would like to submit the following information relative to your efforts on water quality management for estuaries.

In reviewing your data relative to your studies on estuaries and the areas of your concern, we are immediately reminded of the preliminary findings of the Statewide Comprehensive Outdoor Recreation Study presently being finalized by this department. It is quite significant to note that nearly all of the major recreational potentials within the State of Hawaii focuses on shoreline areas and in certain circumstances, in areas of major estuaries such as the Wailua area on Kauai. The importance of proper control and development of estuarine areas is certainly substantiated by the findings to date of our study. The final printing of the study findings will be underway shortly and we would recommend that this be considered under your estuarine studies.

As another source of possible data for your estuarine studies, we would like to inform you of the scenic area inventory for the State of Hawaii consisting of a pictorial and field survey of all of the major points of scenic interest.

These would most probably include many areas of relevance to your estuarine studies. A log of pertinent historical and general information has been compiled for many of these scenic areas to complement the photographs.

We respectfully request that the data indicated above be carefully evaluated in your efforts for water quality management for estuaries.

Sincerely,

Shelley M Mark

Shelley M. Mark

cc: Dr. Quisenberry

SHUNICHI KIMURA
Mayor

EDWARD K. HARADA
CHIEF ENGINEER

COUNTY OF HAWAII
DEPARTMENT OF PUBLIC WORKS
25 AUPUNI STREET
HILO, HAWAII 96720

BUREAUS AND DIVISIONS
AUTOMOTIVE EQUIPMENT & MOTOR POOL
BUILDING CONSTRUCTION AND INSPECTION
PLANS AND SURVEYS
ROAD CONSTRUCTION AND MAINTENANCE
SEWERS AND SANITATION
TRAFFIC SAFETY AND CONTROL

38

38

RECEIVED
OFFICE OF THE DIRECTOR
DEPT. OF HEALTH
1969 FEB 4 AM 44
BY ✓

IGT
2/9/69
Hawaii

January 31, 1969

Dr. Walter B. Quisenberry
Director of Health
Department of Health
P. O. Box 3378
Honolulu, Hawaii 96801

Dear Dr. Quisenberry:

Reference is made to your letter of January 20, 1969, to Mayor Kimura enclosing an invitation to the public meeting on Water Quality Management for Estuaries, which was held on January 28-29, 1969, in Honolulu, Hawaii.

Inasmuch as we were unable to attend the meeting, we submit herewith for the records, three copies of our presentation on Water Quality Management for Estuaries.

Very truly yours,

Edward Harada
EDWARD HARADA
Chief Engineer

Enc.

cc: Mayor

Reproduced from
best available copy.

WATER QUALITY MANAGEMENT FOR ESTUARIES

The County of Hawaii has long recognized the need for maintaining high water quality and we have cooperated with the State Department of Health in the development of water quality standards for Hawaii and now, the quality management for estuaries.

Of particular concern is the Hilo Bay area. Up to the early 1940's Hilo Bay was considered one of the finest bathing, surfing, and boating areas. The entire stretch of the shoreline from the Wailuku River to Wailoa River was covered with fine black sand. On normal days, the bay's blue water was outstanding. This scene was altered drastically by the destructive force of nature and by the work of men.

At present, the seashore recreational areas within Hilo Bay usually frequented by the public extends from the vicinity of Wailoa River to Baker's Beach. The principal congregating area is at Coconut Island. Activities within this reach are mainly confined to bathing and shoreline fishing. Boating is suggested by sheltered Reed's Bay and its natural mooring facilities.

The Hilo Sewer System Study, prepared by Belt, Collins & Associates, Ltd., in 1961, states that Hilo Bay is presently in a state of overtaxation. Accumulation of contaminating material has increased slowly but progressively along the shoreline. Sources of pollution were mainly from sanitary and industrial wastes.

Since 1966, substantial gains have been made to reduce the pollution in Hilo Bay: the construction of the Hilo Sewerage System, Phase I, which now treats the sewage and discharges the effluent into the open sea; the constructio of the Waiakea Peninsula sewer which eliminates the use of cesspools; and the closing of the Flintkote Company's canec plant which was one of the contributors of pollution in Hilo Bay.

To attempt to single out and specifically segregate a particular degree of contribution would require an extensive and comprehensive investigation conducted at strategically established stations in the bay as well as the contributory sources.

The County of Hawaii concurs that protection of our estuaries resources must be administered now along with the recently adopted water quality standards. With the increasing number of tourists, population growth, and availability of leisure time, there is need for maximum use of our shore waters, beaches and navigable waters for recreational purpose.

JOHN A. BURNS
GOVERNOR OF HAWAII

WALTER B. QUISENBERRY, M.P.H., M.D.
DIRECTOR OF HEALTH

WILBUR S. LUMMIS, JR., M.S., M.D.
DEPUTY DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

February 18, 1969

Mr. Donald Mausshardt
Representative Pacific Islands Area
Room 423, 1481 S. King Street
Honolulu, Hawaii 96814

FEB 24 1969

Dear Mr. Mausshardt:

Enclosed are two copies of a statement from the Department of Land and Natural Resources on water quality management for estuarine areas in Hawaii.

Sincerely,

Shinji Soneda, Exec. Officer
Environmental Health Division

SS/lk
Encl.

JOHN A. BURNS
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

DIVISIONS
CONVEYANCES
FISH AND GAME
FORESTRY
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

RECEIVED
OFFICE OF THE DIRECTOR
OF HEALTH
1969 FEB 14 PM 1 03
BY

February 13, 1969

Dr. Walter B. Quisenberry
Director
Department of Health
State of Hawaii
Honolulu, Hawaii

Dear Dr. Quisenberry:

This is in response to your letter of January 20, 1969 inviting our Department to submit statements on water quality management for estuarine areas in Hawaii. We understand that these statements are for inclusion into the records of the State-wide estuarine public hearing co-sponsored by the Health Department and the Federal Water Pollution Control Administration.

The Department of Land and Natural Resources is vitally interested and involved with the management, conservation and development of estuary systems in Hawaii. A large measure of our activities in public land management, aquatic wildlife resources, recreational, historical and archaeological resources, water resources and flood control are located within estuarine areas. Following are comments on specific program areas.

Aquatic Wildlife Resources

Within Hawaii's estuary system, as defined for the purpose of the public meeting, the various commercial fisheries of the State accounted for the harvest during 1967 of nearly 2,000,000 pounds of fish with an ex-vessel value in excess of $845,000. Not included in the above figures is the contribution that nehu (Stolephorus purpureus) made to the commercial fishery.

The nehu, a species of anchovy used as live bait in the aku (Katsuwonus pelamis) fishery, is an estuarine species. The nehu is an absolutely essential ingredient for the Hawaiian aku industry which constitutes the State's largest fishery.

The important nehu producing waters of the State are: Oahu - Pearl Harbor, Kaneohe Bay, Honolulu Harbor and Keehi Lagoon; Maui - Maalaea Bay and Kahului Harbor: Hawaii - Hilo Bay and Kawaihae Harbor; Kauai - Hanalei Bay and Nawiliwili Harbor.

In 1967 with the use of an estimated 224,000 pounds of nehu, 8,000,000 pounds of aku valued at nearly $1,300,000 to the primary producer, the fishermen, were landed in the islands. Thus, directly and indirectly Hawaii's estuary system contributed 10,000,000 pounds of fishery products having an ex-vessel value in excess of $2,000,000 during 1967.

In addition to commercial considerations, the fishery resources are of tremendous recreational and aesthetic value to the people of Hawaii. The proximity of the ocean and the favorable environment for water-related recreational activities of which fishing is a major category, contributes importantly to the quality of life enjoyed by the residents of Hawaii and also offers further inducement to tourists to visit the islands.

The most recent national survey of fishing conducted under the sponsorship of the Bureau of Sport Fisheries and Wildlife of the U.S. Fish and Wildlife Service revealed that 20% of the population surveyed in the United States in 1965 engaged in recreational fishing activities. Inasmuch as those living in Hawaii have ready access to the ocean and since the people of Hawaii traditionally display a close affinity to water-oriented recreational outlets, participation by our people should compare favorably with and possibly exceed the national average. Since, at present, a more reliable estimate is not available, if the 20% national participation level is applied to Hawaii, it would then appear that about 160,000 residents of Hawaii engage in recreational fishing annually.

Whether it be for commercial or recreational utilization, approximately 150 species of finned fishes and invertebrates are being harvested from our estuary system. However, because of ecological interaction such as food chain cycles, the total number of organisms, both fauna and flora, actually involved in the productive process increases by manyfold and any interruption or adverse condition impressed upon the process would detrimentally affect ultimate production.

Another highly pertinent consideration and one which is peculiar to Hawaii when compared with other coastal states is the virtual absence here of a continental shelf and therefore the limited and finite seaward boundary available for the production of fishery resources within the Hawaiian estuary system. Because the Hawaiian Islands are essentially only the exposed tops of steeply rising mountains whose slopes angle sharply down to the base some 12 to 18 thousand feet below the surface of the ocean, the habitable area of our exploited marine fish fauna, except for the pelagic species, consists only of a narrow band of possibly two or three miles in width encircling each island. The severely confined nature of this biotope renders even the most seaward limits subjectable to pollution effects even of terrestrial origin.

Flood Control and Water Resources

Because of our insular geography Hawaii's coastal waters are natural receiving bodies for surface runoffs. During flood flows, sediments from the uplands are deposited in the coastal areas through natural streams and flood control facilities. The near-shore areas are thus affected by storm water pollution.

The Department's flood prevention and control programs are actively pursuing the resolution of pollution to the receiving bodies by assisting, promoting, encouraging and coordinating efforts of federal, state, county and private organizations in implementing programs in regulating the use of flood plains, reduce erosion through land treatment measures, and in the design of flood control facilities with consideration of minimizing pollution to coastal areas from floodwaters.

Public Land Management

Under present arrangements, the Department of Land and Natural Resources is responsible for the management of State lands including lands within estuaries. Any development within these lands require prior approval of the Department.

Recreational, Historical and Archaeological Resources

Essentially, the entire shore areas of Hawaii have recreational as well as historical and archaeological values. Water-oriented recreation such as swimming, water skiing, surfing, skin diving and other water sports are an integral part of Hawaii's culture. Also, historical sites as well as archaeological resources are associated with the many fish ponds located along the island's coastal areas. Control of the quality of stream runoffs appears essential to the full utilization of these areas for recreational uses.

In view of the economic and social importance of Hawaii's estuary system and the extreme vulnerability of this system to the effects of pollution, this Department is in unqualified accord with all studies that will promote pollution abatement and the preservation and wise utilization of our estuaries.

Very truly yours,

BOARD OF LAND AND NATURAL RESOURCES

Sunao Kido

SUNAO KIDO
Chairman and Member

League of Women Voters of Honolulu
P. O. Box 1411 • Honolulu, Hawaii 96806
Telephone 587-061

February 13, 1969

Mr. Irving M. Terzich
FWPCA, Pacific Southwest Region
760 Market Street
San Francisco, California 94102

Gentlemen,

The League of Women Voters of Honolulu is glad to add its support of the following assumptions, which are being used in the National Estuarine Pollution Study:

1. Estuaries have high economic and social values.
2. Attainment of maximum public return from estuarine systems depends on:
   a. Protection of water quality
   and
   b. Land use restriction
3. Pressure for multiple use of the estuarine system will increase.
4. There is a need for a continuing, articulated research program with a broad geographic scope.
5. Attainment of maximum public return calls for a management partnership among Federal, State, and Local agencies.
6. Estuaries cannot be considered independently of their watersheds and Continental Shelf.

We have long favored active citizen participation in the implementation of any Water Quality Standard Program. Cooperation among the Federal State and Local Agencies, as well as concerned citizens is a necessity for an effective management program.

Sincerely,

Elaine Vik
Mrs. Robert V. Vik, President
League of Women Voters of Honolulu

Pat Shutt
Mrs. Ken Shutt
Co-Chairman Water Resources Committee

A Non-Partisan Organization Which Promotes Informed Citizen Participation In Government

HAWAII HOTEL ASSOCIATION

February 12, 1969

Mr. Donald B. Mausshardt, Basin Engineer
Pacific Islands Basin Office, FWPCA
Pacific Southwest Region
1481 South King Street, Rm. 423
Honolulu, Hawaii 96814

FEB 17 1969

Reference: Public Meeting on Quality Management for Estuaries

Dear Mr. Mausshardt:

Please excuse the delay in replying to your January invitation concerning the important conference on estuarine pollution. I have been away from my office for several weeks on an extended trip in Asia. The delay in replying to your communication should not diminish the value or the importance of this subject.

It is my understanding that written comments can be entered into the record up to and including February 17, 1969. The comments that are listed below express the general position of the Hawaii Hotel Association. The Hawaii Hotel Association is composed of approximately 104 active hotel operators in the State of Hawaii. These operators represent 85% of the available hotel rooms in the State of Hawaii. My expressions reflect the concensus of the majority of our Hotel Association members, but do not necessarily carry the unanimous endorsement of all of our members.

The answers to your questions, posed in the memorandum, will be set forth in numbered paragraphs:

1. What are the values of an estuary? The general values of estuaries have been very ably defined many times. The particular values of an estuary in terms of the visitor industry cannot be over-emphasized. The aesthetic, recreational and dollar assessment of the estuary waters of the State of Hawaii are a prime asset of the visitor industry plant and facilities.

2. How have they been damaged by pollution and how much? The pollution damage in estuaries of the State of Hawaii are minimal at this time, but certain areas are detiorating rapidly. A specific example is Kaneohe Bay and Kailua Bay --

ROOM 802 2270 KALAKAUA AVENUE HONOLULU, HAWAII 96815 MEMBER AMERICAN HOTEL & MOTEL ASSOCIATION AH-MA TELEPHONE 923-0407

two areas I am personally familiar with. In addition, many of the off-shore areas of the City and County of Honolulu are experiencing a damaging degree of pollution from raw sewage and silting. The degree of pollution in terms of an absolute scale is not available to me.

3. What do you think the future of our coastal zone should be? The State of Hawaii and the visitor industry of the State are inexorably linked to our estuary system. Destroy Hawaii's estuary system through pollution and you will largely destroy the visitor industry in the State of Hawaii as we know it today.

4. What are the best uses of our estuaries? The prime use of the estuaries must be as a preserve for the natural marine life that habitates the waters surrounding our islands. A secondary use, and a compatible one providing the proper controls are exercised, is recreational. There is no reason why a marine life reserve cannot provide recreation in a properly scheduled and controlled program.

5. What system of management -- local, state and federal -- would best provide for development and protection of our estuarine resources? The standards establishing the conditions of the estuaries should be set by the federal government. The State government should be responsible for seeing that the standards are followed. The Counties within the State can be charged with the actual administration of the standards and the enforcement of the agreed-upon programs.

Thank you very much for allowing our Association to comment on this very important subject. If there are additional questions that need clarification, please do not hesitate to call upon our office. We will be more than happy to cooperate.

Sincerely yours,

Robert N. Rinker

Robert N. Rinker
Executive Vice President

RNR:11

HSPA
HAWAIIAN SUGAR PLANTERS' ASSOCIATION
1527 KEEAUMOKU STREET / HONOLULU, HAWAII 96822 / TELEPHONE 536-2711

HANNIBAL TAVARES
Public Affairs Coordinator

February 13, 1969

FEB 14 1969

Mr. Don B. Mausshardt
Federal Water Pollution Control
Administration
Room 423, 1481 South King Street
Honolulu, Hawaii

Dear Mr. Mausshardt:

Enclosed are statements for inclusion in the proceedings of the recently held public meeting on Water Quality Management of Estuaries.

We also recommend that you include in the proceedings testimony submitted by Robert L. Cushing and the letter from Hannibal Tavares to the public hearing before the Subcommittee on Air and Water Pollution, Committee on Public Works, United States Senate, August 9 and 10, 1967 (title page and contents enclosed).

Very truly yours,

Hannibal Tavares

HT:np

encl.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

P. O. BOX 2450
HONOLULU, HAWAII 96804

June 20, 1967

Statement by Robert L. Cushing on Water Uses and Standards of Water Quality at a Public Hearing Before the Department of Health of the State of Hawaii

June 23, 1967

* * * * * * * * * * *

I am Robert L. Cushing, Vice President & Secretary of the Hawaiian Sugar Planters' Association, and this statement is made on behalf of that association and the 25 sugar plantation companies which are members.

This brief statement will emphasize two points. First, we are in general agreement with the standards and regulations as proposed under your notice dated June 9, 1967 even though, in order to meet the standards as now written, some of our member companies will be required to spend extraordinary amounts of capital without any prospect of return.

Second, if—in the course of review and final acceptance by agencies of the state and federal governments—these standards as now written are made even more restrictive, they will have an adverse economic impact on some plantations in Hawaii. These plantations already are committed to spending large sums of money to begin to bring their operations into conformance even with the present proposed standards.

The sugar industry is pleased that the proposed standards appear to recognize our basic premise that we should be allowed to continue present uses where such uses do not unreasonably interfere with a better present or foreseeable use and until such time as better uses are actually demanded of the water areas in question.

nice, clean, colorless crystal.

But the process of growing, harvesting, and processing the plant -- in our case sugarcane -- is at times a dirty job. For one thing, we need soil to support the plant physically and to provide a medium through which water and the nutrient elements may be provided. Now, it doesn't make any difference whether the farmer is growing sugarcane or wheat or corn or apples or oranges. Farming operations periodically, of necessity, lay the soil bare, and if the bare soil is dry it may be moved about by wind. Any of you who may gave grown up, as I did, in the middle west and who saw the dust bowl of the 1930's, or any of you who have been on Lanai or Maui and have seen the plume of dust being blown off Kahoolawe when there were strong trade winds know what I am talking about.

Similarly, when the soil is bare, and sometimes even when it is not, heavy rains may pick up the soil particles and transport them. This process of soil movement by water is called erosion, and erosion is not necessarily a consequence of agricultural operations. Waimea Canyon, for example, was carved out of Kauai by erosion long before any menehunes or Hawaiians or haoles put a plow to the land.

There is another part of the farming operation that is sometimes a dirty one. When root crops, such as Irish potatoes or carrots, or even lettuce and celery, are harvested, inevitably some soil is brought along with the product. The same is true of sugarcane. With present methods of harvesting, which we have to use to keep our costs competitive, we can't avoid bringing some rocks and soil to the mill along with our cane stalks. We must remove the soil and rocks before the cane is milled. We must also remove leaves and immature portions of stalk before milling. These wastes must, somehow, be disposed of.

Obviously, our dilemma, and the dilemma of every farmer, is how to produce our product with the minimum amount of wind and water erosion and with minimum inconvenience to ourselves and others from the sometimes dirty operations involved in harvesting, cleaning, and processing our crops.

There are a lot of other conversion processes that involve some dirt and waste also, whether it be energy conversion by a power plant, the smelting of ore to make iron and steel, the making of paper, the manufacture of cement, or the production of detergents.

This, to me, is what water pollution control is all about: to try to maintain the agricultural and industrial operations on which our society is completely dependent, while at the same time maintaining water in sufficient quantity and quality to meet the needs for human, plant, and animal consumption and to meet the needs for recreation and esthetics which are also a desirable part of our lives.

The Hawaiian sugar industry has long recognized the need for maintaining high water quality and we have cooperated with the State Department of Health in the development of water quality standards for Hawaii under State and Federal laws.

We believe, and have maintained throughout all of the public hearings held during the past 18 months, that water quality standards must recognize certain legitimate uses for water. We believe that a proper use for some areas of the ocean water surrounding the Hawaiian Islands is for the receipt and dissemination of industrial and agricultural wastes, provided such use does not interfere with other users.

We believe it is proper for the State of Hawaii, which is surrounded completely by ocean and which is more than 2,000 miles from its closest neighboring state, to set water quality standards appropriate to its needs. Problems of interstate streams, where pollution of the waters of a stream in one state may obviously harm users in another state, are different from those in Hawaii. We believe that Federal guidelines designed to meet mainland problems are not necessarily applicable in all respects to our state and should not be imposed arbitrarily in Hawaii.

The Hawaii Water Quality Standards are too voluminous and too detailed to discuss in detail. I will, therefore, refer only to that portion of the Standards which establishes the classes of water use, and specifically to Class I ("eye"). The Water Master appointed by the Director of the State of Hawaii Department of Health determined, after 19 public hearings, that there should be a class of ocean water specifically designated for receipt and dissemination of industrial and agricultural discharges. This is known as Class I. (There are three other classes of coastal waters: AA—for propagation of marine life and for oceanographic research; A—for recreational use, including swimming, fishing, boating, etc,; and B—for large and small harbors.)

Let me emphasize that the Hawaii Water Quality Standards establish basic requirements which all of these classes of water, including Class I, must meet. In addition to meeting the basic standards, Class I waters must meet specific standards for the Class which will provide for improvement of the quality of the ocean waters so designated.

Under the Hawaii Water Quality Standards, Class I provides for zones of mixing. Such zones would be of limited area and would be designated by the Director of the Department of Health only after public hearings. They could be terminated by the Director of Health upon the showing, in a public hearing, that there was a genuine need for such water for even better uses.

In order to meet the basic standards applicable to all waters in Hawaii, some Hawaiian sugar plantations and mills will have to make substantial changes in their current operations. Those few who are now doing so have agreed, for example, that they will discontinue the discharge of cane trash and excess bagasse. In those few instances where the discharge of cane wash-water containing soil particles interferes with other, even better, uses of the water, such as swimming and fishing, such discharges will be stopped. In order to meet the basic standards, these plantations will be required to spend extraordinary amounts of capital with no prospect of return.

The areas for which the Class I zone of mixing will be requested represent only an insignificant portion, no more than 1%, of the more than 1,000 miles of Hawaii's shore line. Moreover, they will be in areas where the coastal waters are not now used for recreation, nor can they be used for this purpose because of sheer and rocky cliffs, dangerous currents and treacherous surf.

We recognize the need for and we support standards which will keep the waters of Waikiki Beach, for example, at the highest possible level of quality. We believe, however, that waters not suitable for swimming, boating, and other recreational uses, may properly be used for the receipt and dispersion of discharges containing soil particles.

Let me emphasize, in closing, that the Hawaii sugar plantations have consistently supported water pollution control, that we have supported and do now support the Hawaii Water Quality Standards as they have been developed and submitted to the

U.S. Department of Interior. The production of food is sometimes a dirty business and I believe that water quality standards must recognize and make provision for the assimilation and dispersion of wastes resulting from the growing and processing of agricultural products.

In summary, let me repeat that the sugar industry in Hawaii believes strongly in being good citizens and good neighbors. We support our state government in its approach to the problem of achieving workable water quality standards for our state—standards which will meet Hawaii's needs without placing undue burden on those who contribute a major part of its economy. We believe it can be done.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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STATEMENT OF E. B. HOLROYDE ON BEHALF OF THE HAWAIIAN SUGAR PLANTERS' ASSOCIATION AT THE PUBLIC HEARING AT KAHULUI, MAUI, HAWAII, RELATING TO WATER USES AND STANDARDS OF WATER QUALITY.

March 22, 1967

My name is E. B. Holroyde, president of the Hawaiian Sugar Planters' Association. I am appearing today on behalf of all the members of that association, which include the 25 sugar plantation companies of the state.

I would first like to express our appreciation to the Watermaster for the abundant opportunity we have had to present lengthy and detailed information in these several hearings, which we have done in the belief that it would be helpful to the Watermaster in reaching fair and equitable determinations.

I would also like to congratulate the Watermaster on the fairness, patience and understanding he has shown in the course of these hearings, and on the manner in which the hearings have been conducted.

We are in agreement with the objectives of a water pollution control program because our industry shares the concern of all responsible citizens for the preservation of Hawaii's natural beauty, and for the health and economic welfare of the citizens of our state. We believe that we must be vigilant to protect our incomparable resources for the generations to come, and that such vigilance must be tempered with fairness and recognition of economic values and necessities. Land is perhaps our most important natural resource, and every reasonable effort should be made to protect and preserve its use. The sugar industry has recognized this for a great many years, and a great deal of study, research, money and effort have gone into preventing or minimizing soil erosion, conserving and making the most effective use of irrigation water, reclaiming waste land with waste materials and soil from factory operations where practical, and minimizing the amount of solids present in discharge water.

Some of these problems are monumental, and at the present state of technology, appear to be without practical solution. Hawaii is different in many respects from the other 49 states. Here we are not dealing with river systems or broad areas of shallow coastal waters, but instead with generally steeply sloping islands, surrounded by a vast and deep ocean. It is this ocean that is at once our pride and our problem. Being non-contiguous to any other state, nothing we do can possibly affect any other state. And being a restless, aseptic, almost limitless receptacle, the ocean would seem to be an ideal means of disposing of degradable agricultural wastes, infinitesimal in volume in relation to the receptacle. In a few areas of the islands, our use of near coastal waters does interfere with better uses; in most areas it does not, and will not do so in the foreseeable future. It is our conviction that water purification is not an end in itself, but that it is desirable only insofar as it serves a useful purpose. It should be noted that in many coastal areas, the plantations have made efforts to reduce the number and volume of discharge outfalls. The dilemma, as we see it, is one of establishing standards of water quality that take into account the unique characteristics and uses mentioned above, and at the same time protect the greatest possible area to the greatest possible extent from serious contamination.

Because of these conditions, it will take time to provide for further and more comprehensive research and study to solve the problems. The sugar industry is prepared to continue to pursue this vigorously. The problem is to find a practical and reasonable means by which to raise the quality of our discharge waters to the high level required by the present objectives of water pollution control. The solution is not yet at hand. Time and a great deal of money will be required. It seems reasonable to assume that we can count on advice and assistance from state and federal agencies, including some form of tax relief, grants for research and construction, low cost loans, or other tangible assistance.

The problem confronting the Watermaster is difficult, and we fully appreciate the time and thought that he and others have given to it. We believe the proposed water quality standards and classifications set forth in the Watermasters's revisions of March 15th have recognized to a large extent the unique conditions found in Hawaii, and we are in general agreement with those revised standards as we understand them. The sugar industry has in no way tried to avoid water pollution control and has come a long way toward reaching a compatible solution. It has been our goal to cooperate to the fullest extent.

It is our understanding with respect to the presently revised standards that the individual plantations will not be held responsible for storm water discharge from their lands providing the plantation has in effect an approved and comprehensive soil conservation program; that present agricultural uses of fresh water streams may be continued; that permits will be available to those plantations which discharge floating material in order to give them reasonable time to cope with their special problems; that the new Subclass is specifically designed to provide an interim period for the discharge of agricultural waste water into certain designated zones, and that testing will be conducted on a basis which permits reasonable mixture and dispersal to take place before actual samples are taken.

It might be pertinent to say at this point that we are assuming that the administrative procedures relating to implementation, review, and enforcement will accommodate the demonstrated need for considerable time in which to make necessary adjustments in present agricultural practices. We have worked closely with the Department of Health for many years in other areas, and we will continue to do so. We believe they are dedicated to doing a very able and conscientious job.

I have nothing further to say except that the industry has taken the view that this matter is of tremendous future importance to our state, and that the present proposed standards and classes represent a reasonable and fair compromise as between present competing uses, and as betweeen the very practical present and the largely unforeseeable future. Again, our thanks for the opportunities to give you our views.

I have appended to this statement several specific questions and suggestions regarding procedures, etc., which I commend to the Watermaster's attention.

Thank you.

APPENDIX TO

STATEMENT BY E. B. HOLROYDE

ON BEHALF OF THE HAWAIIAN SUGAR PLANTERS' ASSOCIATION BEFORE THE WATER MASTER OF THE STATE OF HAWAII ON WATER QUALITY STANDARDS.

I. It is recommended that "Subclass I" be substituted for "Subclass BA" throughout.

Comment. We understand that the new interim subclass for receiving agricultural waste waters containing soil particles was not intended to be limited to "B" waters. The designation "BA" implies that it is. The suggested designation removes this unintended implication.

II. It is recommended that the last sentence of the comment explaining the new subclass be changed to read: "It is recommended that the Director consider these demands through a procedure analogous but separate from the permit procedure provided by the Regulations. The outlines of this procedure are spelled out below under the title, 'Recommended Division of Water Areas--Subclass I Waters--All Islands.'"

Comment. The matter of establishing subclass 1 waters should be kept separate from problems involving permits. The purpose of the two procedures, the facts relevant to applications under them, and the bases for granting the applications are quite different. Combining the two procedures would lead to unnecessary confusion.

III. It is recommended that under "Recommended Division of Water Areas," the following be provided:

"SUBCLASS I WATERS. ALL ISLANDS.

If, upon the application of any person actually demanding a water area for agricultural or industrial uses, the Director of Health determines (1) that water meeting the quality standards for subclass I waters will not unreasonably harm or interfere with any use actually demanded of the water area for which it is otherwise classified, and (2) that relevant factors controllable by the applicant have been controlled where reasonable and practical controls are available, then such water area shall be subclass I waters and the water quality standards for subclass I waters shall apply thereto. No application shall be denied unless the applicant has had an opportunity for a hearing by the Director. Such hearing shall be in accordance with the Hawaii Administrative Procedure Act and the Rules of Practice and Procedure of the Department of Health."

Comment. See Recommendation 2.

IV. It is recommended that Water Master expressly provide that both the "general" and the "additional" water quality standards apply to water areas after reasonable dilution and mixture has occurred therein.

Comment. We understand that standards are to apply to the receiving water, not to effluent.

V. It is recommended that the Regulations relating to water pollution control be amended in the following respects:

A. Section 2 should be revised to expressly provide for revision of the water quality standards as the need arises. The Rules of Practice and Procedure of the Department of Health and the Hawaii Administrative Procedure Act would seem to provide the appropriate vehicle.

Section 2, then, might be revised as follows:

"Section 2. STANDARDS OF WATER QUALITY.

. The Director may appoint a Master who shall divide the waters of the State into areas and who, after investigations and hearings conducted in accordance with the Rules of Practice and Procedure of the Department of Health, State of Hawaii, shall recommend standards of water quality applicable to such water areas. The standards of quality recommended by the Master shall be such as to protect the present and prospective best use of each water area. Consideration shall be given by the Master to the standards and requirements of other government agencies having legal responsibilities for water quality control.

"The Director may adopt the recommendations of the Master or any modification thereof and from time to time may amend or repeal those adopted or any part thereof. Any such action taken by the Director shall be such as to protect the present and prospective best use of each water area in the State. Standards of water quality or any amendment thereof shall become effective upon their adoption by the Director and publication of notice of such adoption in a newspaper of general circulation in the county or city and county concerned. Such standards shall remain in effect until amended or repealed by the Director.

"The adoption, amendment, or repeal of standards of water quality or the division of the waters of the state into areas shall be in accordance with the Hawaii Administrative Procedure Act and the Rules of Practice and Procedure of the Department of Health."

B. Section 5 should be revised as follows.

1. The basis for obtaining a permit should be altered slightly to make it certain that a disappointed applicant does not have an impossible burden should he seek judicial review.

2. The language relating to the renewal of permits should be changed to make it clear that there may be occasions in which more than one renewal of a permit is appropriate. Technology is too uncertain at this point to accurately predict when the Director should no longer be able to grant renewals.

3. All persons having potential water quality control problems should be encouraged to apply for permits. They will not do so if they fear that applying for a permit or operating under one might be construed as an admission that their discharges violate the law. Section 5 should be revised to make it clear that applying for or operating under a permit will not prejudice the applicant or the permittee.

4. All persons should be able to know what they must do in order to avoid violating the law. Water pollution control is a field frought with uncertainty. A procedure by which any person could obtain an advance determination that his discharge is not polluting the water would have several propitious effects:

a. It would encourage persons to report their water problems to the Director and thus provide a broader base of knowledge on which to carry out water pollution control.

b. It would enable businessmen to lay solid foundations for business planning.

c. It would enable persons, especially individuals and small businessmen, to obtain relevant technical advice, which otherwise will not be available to them.

d. It would enable all persons to determine with dependable certainty what water pollution control measures they must take, if any, in order to comply with the law.

To attain these goals, section 5 of the Public Health Regulations on water pollution control might be amended to read as follows:

"Section 5. ISSUANCE OF PERMIT.

Applications for permits will be reviewed together with plans, descriptions and histories submitted by the person making such application and together with such additional information as may be requested by the Director to ascertain the effect or probable effect upon the standards of water quality established for the water area involved. No permit nor renewal thereof shall be issued by the Director unless the application and the supporting information clearly show, (1) that the issuance thereof is in the public interest, or (2) that the denial thereof would cause inequitable hardship to the applicant. No permit nor renewal thereof shall be denied unless the applicant has had an opportunity for a hearing by the Director.

"The Director may issue and from time to time renew a permit for any period not exceeding five years. Upon expiration of the period stated therein or in any renewal, the permit shall automatically terminate and no rights shall become vested in the permittee.

"Each permit shall stipulate the conditions under which it is issued. Any person to whom a permit has been issued may apply for a change in the conditions of the permit. A statement of the reasons for requesting such change shall accompany the application.

"No person shall be deemed to have admitted that a permit was required by law or shall otherwise be prejudiced by (1) applying for a permit or any renewal thereof, or (2) acting in accordance with the terms of any permit or renewal issued hereunder.

"If upon the consideration of such application or after such a hearing or if upon the application of any person the Director determines that the discharge covered by such application does not unreasonably harm any use for which the water area affected is classified, he shall enter an order accordingly. Such order shall constitute neither the issuance nor the denial of a permit, but shall be a determination that a permit is not required. Such determination shall be conclusive against the Director until the order is revoked in the manner provided for the revocation of permits hereunder."

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STATEMENT BY

ROBERT L. CUSHING, VICE PRESIDENT-SECRETARY AND DIRECTOR OF THE EXPERIMENT STATION, HAWAIIAN SUGAR PLANTERS' ASSOCIATION, RELATING TO WATER POLLUTION CONTROL AND WATER QUALITY STANDARDS, BEFORE THE DIRECTOR OF HEALTH AND THE BOARD OF HEALTH, STATE OF HAWAII

DECEMBER 15, 1967

It is clear that on the mainland there must be some arbiter of the conflicting demands for water made by the citizens of different states. It is only proper that that arbiter be an agency of the federal government, for we are all citizens of the United States. But in Hawaii there are only the conflicting demands of the people of this state. There are no problems here requiring needless intervention by the federal government. Hawaii's boundaries are common with no other state. Hawaii stands in the middle of the great Pacific Ocean, 2,400 miles from any other state. Our waters are principally coastal waters whose currents influence the waters of no other state. There are no streams in Hawaii that run interstate. Such streams as we have are fed from mountains, whose soils are unique, by rains at rates too great for those soils to assimilate. Hawaii's waters run not into other states, but into the vast Pacific Ocean. No one is harmed, no use interfered with outside the boundaries of Hawaii.

We are here today to consider revisions to the water quality standards adopted by the Director of Health and approved by the Governor of this state. The officials of the Federal Water Pollution Control Administration (FWPCA) are here to see that these revisions demanded by their reviews are made and perhaps even to propose still further revisions. They claim they are necessary in order to protect the proper use of our waters. They claim authority to tell us so under the Federal Water Quality Act.

We note from the draft which is the subject of this hearing that the permit system has been retained. The purpose of this system is to authorize the Director of Health, under the Hawaii water pollution control statute, to consider the public interest and to permit a delay in compliance with water quality criteria under limited, supervised conditions where the public interest demands it. We note, too, that there is provision for "zones of mixing" which recognizes that discharges causing unreasonable harm to other legitimate uses of Hawaii's waters must be stopped. But discharges which do not interfere with other uses may be maintained. Finally, we note that there is no provision for review by the FWPCA of the decisions to be made by the Director both under Chapters 37 and 37-A and under the implementation plan.

Yet, we are concerned. We are concerned because we foresee that the FWPCA will make every effort to exert the power it thinks it has to usurp primacy over Hawaii's waters, notwithstanding that even the federal statute expressly reserves that primacy to the government of this state.

First, the FWPCA seeks to control the use of Hawaii's waters. The federal statute is explicit to the contrary. Section 1 (b) states that "(I)t is hereby declared to be the policyof Congress to recognize, preserve, and protect the primary responsibility and rights of the States in preventing and controlling water pollution." In rejecting the notion that the FWPCA ought to have primary responsibility, the House Committee on Public Works in its report on the bill that became the Federal Water Quality Act of 1965, stated,

> It would place in the hands of a single federal official the power to establish zoning measures over — to control the use of — land within watershed areas in all parts of the United States. Such power over local affairs has never been vested in a federal official, and we are opposed to doing it now. [H.R. No. 215, Public Works Committee, 89th Congr., 1st Sess., March 31, 1965, U.S. Code Congressional and Administrative News 3322 (Additional views in support of S.4)]

But neither the House Report nor the federal statute slowed the FWPCA's efforts to displace local control. It has used a variety of sophisticated devices. For example, the FWPCA assigned the task of developing water quality criteria to the National Technical Advisory Committee (NTAC). The next step was simply to require each state to conform its standards to the recommendations of the Committee. Accordingly, Mr. Schreeder, Regional Director of the Southwest Region of the FWPCA, in his letter to Dr. Quisenberry dated September 26, 1967, stated that it was necessary that Hawaii change its standards to conform to the report of the NTAC where differences existed.

A second device was the use of "guidelines". Guideline 2 of those published in May of 1966 states,

> No standards of water quality will be approved which provide for the use of any stream or portion thereof for the sole or principal purpose of transporting waste.

From the questions and testimony of the legislative oversight hearings, held by the Subcommittee on Air and Water Pollution, Committee on Public Works, U.S. Senate, on August 9 and 10, 1967, we must assume that the FWPCA interprets this guideline to mean that the Pacific Ocean may not be used for the assimilation of untreated waste. In those hearings Mr. Di Luzio, Assistant Secretary of Interior for Water Pollution Control, said,

> That gets to the basic question of whether water being used as a carrying vehicle or as an absorption factor for waste is a beneficial one.
>
> We have denied this over and over and over again to our states because once they get in the pattern of saying, this section of the river should be used as a waste carrier because it is not good for anything else, we are foreclosing selection or election of use of these streams by future generations. [Stenographic Draft of Transcript of Hearings Before the Subcommittee on Air and Water Pollution, Committee on Public Works, U.S. Senate, Aug. 9 & 10, 1967. p.68. (Hereafter cited as "Transcript.")]

Senators Fong and Inouye pursued the problem of control over local water uses in a set of questions directed to the FWPCA. It responded:

> (T)he Department . . . has the duty under the Federal Water Pollution Control Act, as amended, to see to the orderly development and the enhancement of the Nation's water resources. At times this requires a regional or even national approach to the assignment of water use priorities. Clearly, in giving the Secretary of the Interior the approval of water quality standards for interstate waters, the Federal Act provides for the Secretary to have a determining voice in assignment of water uses.

In his letter dated September 26th, Mr. Schreeder told Dr. Quisenberry to delete provisions for the present permit system and for Class I waters. The permit system and the zones of mixing remain. They represent local control over Hawaii's waters. We fear that the FWPCA will seek to neutralize them by attempting to influence their administration.

Second, the FWPCA has failed to respect the requirement in the federal act that water quality control is to be for the protection of persons. Section 10(a) of the Federal Water Quality Act of 1965 expressly states,

> The pollution of interstate or navigable waters in or adjacent to any state or states . . . which endangers the health or welfare of any persons, shall be subject to abatement as provided in this act. (Emphasis added.)

Yet, Mr. Di Luzio in the Senate oversight hearings on August 10th, said,

> We must abate pollution, not only for human consumption, but also to protect the life organisms. It is not limited only to water for humans. That is the big difference in some circles. If I may say something sacriligious, that is the difference between the public health approach and the resource management approach. The public health approach worries about the effect of the water quality upon man, but a resource approach worries about the effect of water quality on the total ecology. (Transcript, p. 153. See also p. 60.)

Third, the FWPCA appears to be basing its demands on speculation. The Hawaii Watermaster, in his report dated April 24th, stated in connection with sediments discharged into Hawaii waters,

> The hearings have developed no facts upon which a conclusion that these waste discharges are detrimental to marine life could be based, although such a conclusion, after more detailed study, might be supported.

All the NTAC report says is that increased turbidity in the ocean will diminish primary productivity. Nothing at all is said about possible beneficial secondary effects. (NTAC, Interim Report, Water Quality Criteria for Fish, Other Aquatic Life and Wildlife, p. 223.) Mr. Di Luzio himself stated on two separate occasions in the legislative oversight hearings on August 9th that it was not the turbidity produced by sediments in the water, but rather the nutrients they carried which were of concern to him. (Transcript, pp. 60, 71.) But the fact remains that no one knows what effect even nutrient materials will have on marine life. According to the NTAC,

> Very little research has been done to determine what interaction of factors causes a shift in diversity or in the kinds of species that compose a community. For these reasons it is impossible to set any definite requirements. At this time the only meaningful thing that can be done is to develop guidelines. (Emphasis added.) (NTAC, Interim Report, Water Quality Criteria for Fish, Other Aquatic Life and Wildlife, p. 240.)

But the FWPCA seems to say that even where we do not know what harm a material will do, we should prohibit it. If the FWPCA later finds that it will not do harm, then perhaps it will allow it. But we think it is a fundamental principle of our state and federal constitutions that one's liberty is guaranteed until there are facts demonstrating at least that the exercise of that liberty threatens harm or detriment to another person. There is no room in our law for speculation.

Fourth, the FWPCA insists on criteria which are either ambiguous or unattainable. Everyone agrees that no person ought to be allowed to use Hawaii's waters to the detriment of another. But at the same time, a person must know what he must do in order to conform his conduct with the law. Every person is entitled to know what he must do in order to avoid committing a crime.

At the insistence of the FWPCA, the concept of best practical treatment or control has been written into the definition of each of Hawaii's water use classifications. The ordinary discharger will likely read this language as simply requiring him to accord whatever treatment or control is necessary to his effluent prior to discharge or enable him to comply with the standards established for the water area involved. If this is what the requirement means, it is not ambiguous. If it means anything else, it is ambiguous. If it means anything else, it will be impossible for him to tell what he must do to his effluent prior to discharge in order to avoid committing a crime. Surely, our water quality standards do not require a discharger into Hawaii's waters, whether truck farmer or sugar plantation, to suffer fine or imprisonment just because the quality of the treatment he accords his discharge does not satisfy the FWPCA, even though his discharge does not cause the receiving waters to fall below the standards adopted by Hawaii's Director of Health.

Not only are dischargers entitled to know what they must do in order to conform their conduct to the law, but they also are entitled to standards which are attainable. Standards which are not attainable are standards which in effect prohibit any discharge whatsoever. The sugar industry is especially concerned about the turbidity standard in Class A waters. You will recall that Mr. Di Luzio stated on two separate occasions in the legislative oversight hearings that it was not the soil particles themselves which were of concern, but rather what they carried. The reference here is to toxic materials and nutrients. But Hawaii's standards contain not only rigid criteria for nutrient and toxic materials, but also a turbidity standard requiring that there be no change from natural conditions by more than

10% in Class A waters. The 10% figure first appeared in Hawaii standards after the interim review by the regional review panel in San Francisco during the middle of May of 1967. The figure is an arbitrary one, apparently pulled out of the air by officials of the FWPCA in San Francisco. Is this standard attainable? The question was answered by Mr. Di Luzio, himself, in the legislative oversight hearing on August 10, 1967:

> There are other things which are not as bad, but they are still damaging to taste, color. They are not toxic, but you really would like to remove them. -- Such as the sedimentation problem in Hawaii we talked about. We would like to get rid of that, but there is no economical way you can do it now. (Transcript, p. 155.)

In view of Mr. Di Luzio's statement, we urge the deletion of the specific turbidity standard for all classes. Not only is it presently unattainable, but also there is no need for it. One of the basic standards (Sec. 6, A, 3) in the draft being considered today is expressly addressed to turbidity. Indeed, it is the very criterion recommended by the NTAC Committee on Esthetics and Recreation. (NTAC, Interim Report, Water Quality Criteria for Recreation and Esthetics, p. 4.) It is entirely consistent with the recommendation of the Committee on Fish, Other Aquatic Life and Wildlife. (NTAC, Interim Report, Water Quality Criteria for Fish, Other Aquatic Life and Wildlife, p. 230.) But even the general turbidity criterion will have a serious impact on sugar plantations who cannot establish the requisite foundation for a zone of mixing. Thus, it is doubly important that the permit system as presently written be retained without change.

The permit system is a mechanism by which the Director of Health can recognize those instances in which the public interest requires that a delay in compliance be permitted. If the FWPCA is allowed to frustrate the state's administration of the permit system, then criminality will attach to every discharger who fails strictly to comply with the standards. Criminality will attach even though the discharger could not tell what he must do to comply. Criminality will attach even though the discharger's financial condition precludes him from complying. Criminality will attach even though technology is not yet available to enable him to comply. Criminality will attach even though the public interest will not be harmed. Obviously, the permit system must be preserved.

Fifth, the FWPCA has not followed acceptable administrative practices. Senate Report 10, appealed to so often by the FWPCA, expressly provides,

> The standards are to be formulated in accordance with accepted administrative procedure, calling for notice and public hearing . . .

Section 10(c)(2) of the Federal Water Quality Act of 1965 sets out detailed procedures to be followed by the FWPCA for the adoption of federal standards should the state standards be unacceptable. This procedure requires reasonable notice and a conference of representatives of the federal and state agencies concerned and the municipalities and industries involved. If one is demanded, the Secretary of Interior must call a public hearing. At least one member of the hearing board is to be appointed by the state. On the basis of evidence presented, the hearing board is to determine whether the Secretary's standards should be approved or modified. If the latter, the Secretary of Interior must modify its standards accordingly. The FWPCA seeks to avoid this procedure in formulating federal standards for Hawaii. The FWPCA caused the adoption of an implementation plan written by one of its own officials by the simple expedient of rejecting out of hand the submission of the Department of Health in the final hours before the June 30th deadline. It reviewed the Hawaii standards after they were adopted on June 29 without any opportunity accorded to a representative of Hawaii's Department of Health or its Watermaster to explain the facts peculiar to Hawaii on which they were based or to defend them against federal attack. As a result of its review, FWPCA announced that the Hawaii standards were deficient in eleven respects. Mr. Schreeder came to Hawaii in early October to obtain the correction of these deficiencies to the satisfaction of the FWPCA. It is remarkable that officials of the State Department of Health and their staff preserved as much of the substance of the Hawaii standards as they did.

The history of FWPCA participation in the development and review of Hawaii Water Quality Standards causes us much concern. Therefore, we urge that the Director of Health take care to avoid the prejudice which will accrue to Hawaii should the FWPCA continue on this course. Hawaii's administration (the Governor, the Director of Health, and the Attorney General) and Hawaii's legislature must resist any further effort of the FWPCA to eliminate or substantially modify the permit system established under Section 3A of Chapter 37 of the regulations of the Department of Health and the zone of mixing concept under Chapter 37A. But more important, the State of Hawaii must resist federal interference with their administration.

While it is true that the sugar industry is an important contributor to the economic well-being of the state, and that we are seriously concerned as an industry about the unusual and unwarranted course now being pursued, we are equally concerned about the effect it can have on other businesses and industries.

* * * * * * * * * * * *

12/12/67
RLC:id

STATEMENT OF ROBERT L. CUSHING, VICE PRESIDENT, HAWAIIAN SUGAR PLANTERS' ASSOCIATION

I am Robert L. Cushing, Vice President of the Hawaiian Sugar Planters' Association, and this statement is made on behalf of the Association and all of its members. I reside in Honolulu, Hawaii.

In accordance with the Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965, and with Act 163, Session Laws of Hawaii, 1965, the State of Hawaii had adopted standards of water quality and has submitted them to the Federal Water Pollution Control Administration of the U.S. Department of the Interior.

These water quality standards were adopted by the Director of the Hawaii Department of Health on June 29, 1967, and were approved by the Attorney General and the Governor of the State of Hawaii. The Watermaster, appointed pursuant to Act 163, held 17 public hearings and conducted extensive investigations on which to base his recommendations to the Director of Health. The Director held two public hearings prior to adoption of the standards; thus, these standards of water quality for Hawaii represent the result of long and thorough consideration of the problem.

Hawaii is unique in several respects. It is the only state completely surrounded by water. It is noncontiguous, being separated from its nearest neighbor state by some 2,400 miles of ocean, and, therefore, its practices cannot possibly affect the water used by any other state. It has exceedingly heavy rainfall in many areas, annual averages of 200 inches being common, and this causes problems in run-off and erosion control of a magnitude not found in any other state.

Agriculture, principally the growing of sugar cane and pineapple, has long been, and continues to be, the backbone of Hawaii's economy; but the products of these crops must be sold in intensely competitive markets on the mainland. It is essential for Hawaii that it continue to be economically feasible to produce these crops.

The water quality standards adopted by the State of Hawaii include a classification of coastal water use designed as "Class I" (eye). This class of waters is to be used as a zone of mixing for the assimilation of municipal, agricultural and industrial discharges which have received the best practicable treatment or control, or such lesser degree of treatment or control as will provide for a quality commensurate with the classified use of the waters outside the zone of mixing. The basis for establishing such classification of use is set forth in Section II, E, of the Hawaii water quality standards.

The Class I water areas are important to sugar growers and processors because some undesirable plant material (leaves, tops, young stalks, etc.) and soil are inevitably brought along with the mature cane stalks in harvesting, and must be removed and disposed of at the mill. In most cases, disposal is not a problem for the purposes of this discussion; however, a major problem exists at all those mills located on the Hamakua coast on the island of Hawaii, below cane fields which extend upward for several miles and run in a broad belt along the lower mountain slopes.

The trash and soil are removed from harvested cane by washing, and enormous quantities of water are used, and must be disposed of at some mills. This wash water, containing soil particles and cane trash is discharged into the ocean. (In a few instances the fibrous residue of the cane, commonly called bagasse, is also discharged.) In the immediate area of such discharges the ocean water is discolored, but the Hawaii proceedings brought out no evidence that there was any harmful effect other than the esthetic one.

Contrary to the possible view that Class I merely provides for continuation of practices which are incompatible with Federal Water Pollution Control Administration guidelines, waters assigned this classification must meet *all* of the "Basic Quality Standards Applicable of All Water Areas" and must, in addition, meet *specific* standards applicable to the particular water areas. Designation of areas as Class I water would be made by the Director of the Department of Health only upon application and after a public hearing. Termination of Class I assignments could be made by the Director of the Department of Health upon his own motion or on application by any person, again after a public hearing.

Compliance with the basic standards and with specific standards for Class I waters will necessitate substantial changes in current practices. For example, the basic standard No. 2 requires that all waters be free of floating debris, so the discharge of cane trash and bagasse will have to be stopped and alternate methods of disposal found. This our industry has agreed to do. These changes will require expenditure of extraordinary amounts of capital by many sugar companies.

Areas designated as Class I will be limited and clearly defined. They would never constitute more than an insignificant proportion (not to exceed an estimated two percent of Hawaii's coastline). They would only be assigned to areas which are inaccessible, are unsuitable for other uses, or clearly not now needed for other uses.

The Hawaii Watermaster's reports and recommendations recognize that in areas assigned Class I, the only effect would be on the appearance of the receiving waters in the zone of mixing. They further recognized that Class I assignments would be for limited areas, in places where there are no beaches and where the shore is in fact inaccessible or dangerous for fishing, so that recreation uses would not be deprived by such assignments. They also recognized that, even though the quantities of discharges are large, they are infinitesimal in comparison to the volume of the ocean waters receiving them, and that there is no demonstrated effect on marine life, because of the thorough mixing and dispersion that so quickly occurs.

The premise on which specific water areas would be assigned to Class I is that these areas either are not desirable or are plainly not essential for other uses. Thus, where agricultural use under Class I does not interfere with legitimate demands for the use of receiving waters by others, the agricultural use should be established as the best use of the water.

Mr. Chairman, the State of Hawaii has labored long and diligently to comply with the provisions of the Water Quality Act of 1965 and the guidelines promulgated by the Secretary of the Interior. It has recommended regulations which will result in a vast improvement in the quality of Hawaiian waters. These regulations will require much more stringent standards of performance by Hawaiian industry, agriculture, the government entities, and the military establishments. They are, we are convinced, sound, workable regulations which, at the same time, recognize the need for maintaining the economic well-being of the State. We do not believe that the Congress, in enacting this important legislation, intended to go further.

Mr. Chairman, we greatly appreciate the opportunity you have provided us to present our views on a matter which is vital to our state—and our industry. Thank you very much.

Senator FONG. And also the letter from the Hawaiian Sugar Planters' Association relative to the problem.

(The letter of the Hawaiian Sugar Planters' Association is as follows:)

HAWAIIAN SUGAR PLANTERS' ASSOCIATION,
Honolulu, Hawaii, July 7, 1967.

MR. SANFORD L. PLATT,
Vice President,
Hawaiian Sugar Planters' Association,
Washington, D.C.

DEAR SANDY: After many months of effort and over 20 public hearings, Hawaii's Department of Health has adopted water quality standards for the entire state. These standards are now subject to review by the U.S. Department of the Interior.

We understand that two Federal review boards will review the standards before they go to the Secretary of the Interior for final approval or rejection. The first review will be made by the regional review board in San Francisco on or about August 3. The names of the members are in the attached memo (Attachment #1). The recommendations of this board will be sent soon thereafter to the Internal Review Board, chaired by James Quigley, Commissioner, FWPCA. I don't know the make-up of this board, but both boards are comprised only of personnel of the Interior Department. Their meetings are not open to the public, according to Charles Bourns, their Hawaii representative.

We can live with these standards as we understand them. We noted a few bothersome technicalities in the finished product but these, we feel, can be handled satisfactorily on the local administrative level. The official record contains a great deal of information submitted by us and others to support our understanding of the standards.

We do not want these standards substantially changed by the Department of the Interior. Hawaii has worked long and hard in establishing standards which we feel will control adequately water pollution in Hawaii. We want them to be given a chance to work without federal interference.

The standards' most important feature to the sugar industry is the provision for Class I zones. These zones may be established at various points along the shoreline by the Director of Health, after public hearings, for the purpose of receiving discharges which meet well defined standards and which will not unreasonably harm the actual uses of the surrounding waters. This is in line with the basic premise we have pushed from the beginning when we pointed out that present uses of the waters should be permitted where they do not unreasonably interfere with better uses actually demanded of these waters.

It should be noted that Class I standards are restrictive, not just anything can be dumped into a Class I zone. The six basic standards which apply to all classes, as well as standards relating to bottom and reef deposits, microbiological requirements, pH units, nutrient materials, dissolved oxygen, and turbidity also apply to Class I. The standards call for the enhancement of all classes of water, including Class I. Class I will not be established without careful consideration. The standards specifically provide a procedure which places certain burdens on the applicant for such a class and which adequately protects the public interest. Therefore, the sugar industry cannot be accused of "getting away with murder" by the inclusion of Class I.

Class I zones will affect less than two per cent of our more than 1,000 miles of coastline, leaving almost unlimited areas for recreation, fishing, conservation, marine research and the like. No reasonable person would argue that *all* of the Hamakua coast should be classified the same as Waikiki, yet most of it is (Class A) and we don't object as long as a few Class I zones are allowed at various points along the coast. Miles and miles of Class A waters still will remain along the Hamakua coast.

Also, any Class I zone duly established can be abolished by the Director of Health in following procedure specifically included in the standards if he finds that it interferes with a better use. In other words, Class I zones are not "locked in" forever.

Much of the rationale for Class I is contained in the recommendations submitted officially by Robert Dodge, Hawaii's Watermaster, to the Hawaii Department of Health. It is attached as Attachment #2.

If no provision had been made for the discharge of cane wash waters and irrigation overflow, several of our plantations would have been in serious difficulty. The elimination of trash and bagasse discharges alone will be a heavy burden on them. You will recall that we have agreed to stop the discharges of trash and bagasse, given time to develop the technology and means to do so. Discharges of this type probably will continue on an interim basis under the permit system provided in the standards and should not be confused with Class I discharges.

Some of the plantations in areas where Class I applications will be made are very low profit companies. In their testimony, they pointed out that meeting the standards without a Class I was economically unfeasible, that they could not stand the cost of eliminating all discharges. Other plantations which are handling this adequately are doing so largely because their mills are located far enough away from the shoreline so that there is sufficient makai land to allow them to dispose of their discharges in various ways. But those with mills located near the shoreline are stuck. There is no inexpensive way of disposing of their discharges. Therefore, Class I is their salvation.

A review of statements by Mr. Edward Holroyde (March 22, 1967) and Mr. Robert Cushing (May 19, 1967) which I have forwarded to you already will give you the details of our major arguments. The attached Fact Sheet (Attachment #3) digests these arguments. I am including extra copies of this sheet since you may want to leave them with people you talk to. Material on economics is being prepared by Brewer and will be forwarded shortly. The final standards also are attached as Attachment #4.

Let me know whether you need additional information or any help from any of us here. This is so important to the sugar industry that our committee wants to be sure that everything necessary is done to prevent the Federal government from rejecting Hawaii's standards.

We will be looking forward to advice and guidance from you.

Very truly yours,

HANNIBAL TAVARES,
Public Affairs Coordinator.

A PROGRESS REPORT
ESTUARINE POLLUTION IN THE STATE OF HAWAII

TECHNICAL MEMORANDUM REPORT NO. 15

December 1968

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF HAWAII
Honolulu, Hawaii

ESTUARINE POLLUTION IN THE STATE OF HAWAII

Technical Memorandum Report No. 15

A project of the Water Resources Research Center in cooperation with the Hawaii Institute of Marine Biology and the Departments of Agricultural Economics, Geosciences, Microbiology, and Oceanography.

December 1968

The research upon which this publication is based was performed pursuant to Contract No. 14-12-446, with the Federal Water Pollution Control Administration, Department of the Interior.

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ESTUARINE POLLUTION IN THE STATE OF HAWAII

PROGRESS REPORT

Introduction

This report summarizes progress in the first half of a 1-year study of pollution of estuaries in the State of Hawaii undertaken by the University of Hawaii for the Federal Water Pollution Control Administration under contract no. 14-12-44o.

The study includes a) an extensive survey of the problems of pollution of estuaries throughout the state, and b) an intensive study of the ecology, the sources and extent of pollution, and the economic implications of pollution control standards at Kaneohe Bay.

Responsibility for the several sub-projects that make up the study is as follows:

Sub-project	Manager
Statewide Survey	R. J. Fuchs
Kaneohe Study	
Sanitary Quality	N. C. Burbank, Jr.
Mineralization	K. R. Gundersen
Organics	K. E. Chave
Plankton	R. Clutter
Sedimentation	R. M. Moberly and P. F. Fan
Alternatives	L. S. Lau
Economics	J. R. Davidson

The study as a whole is coordinated by a committee composed of V. E. Brock, N. C. Burbank, Jr., D. C. Cox, J. R. Davidson, and L. S. Lau.

This report presents a definition of estuaries adopted for the study, a review of estuaries in the state known or suspected of being polluted, reports on progress in the several sub-projects involving Kaneohe Bay, and a working bibliography. It should be emphasized that much of what is presented here is preliminary. Although the estuaries for study have been identified, information has not been assembled for most of them. Conclusions cannot yet be reached in most of the Kaneohe field studies. Many of the material in the bibliography have yet to be scanned. The completion of the field work and the formulation of final conclusions are, of course, the aims of the second half-year of the project.

The project personnel have profitted from the meetings when the study began with Dr. Harold Berkson, who was assigned to the project as project officer by the Federal Water Pollution Control Administration, and in October 1968 with Dr. H. J. Odum of the University of North Carolina, who was making an overall, more general national study of estuarine pollution.

PART I. STATEWIDE STUDY

DEFINITION OF ESTUARIES

by

Doak C. Cox

DEFINITION OF ESTUARY FOR THE HAWAIIAN STUDY

The term estuary has been defined and used in a variety of ways, some of the meanings assigned to it even being mutually exclusive. The etymology of the term and its definitions and usages are here reviewed to determine the definition most suitable for use in the University of Hawaii study of estuarine pollution in the state of Hawaii. Although the definition of an estuary and its distinction from other similar features is less important than the recognition and quantification of the important characteristics that might be used to make the distinction, it is still desirable that estuary, as a technical term, have a precise meaning as possible. Even Russell (1967) who regards taxonomic exercises as "fruitless and unjustified because our knowledge of coastal features is so incomplete" grants that "it is necessary to recognize major types." Special attention is given here to the various geomorphic, hydrodynamic, and hydrochemical criteria used in distinguishing estuaries. Typical sedimentological and biological assemblages have been described as estuarine, but these seem to be defined on the basis of their typical occurrence in estuaries identified on the basis of geomorphology, tidal behavior, and salinity rather than used as criteria for identifying estuaries.

Etymology and Common Usage

The etymology sometimes indicated for estuary, from the Latin *aestus* = heat, boiling, bubbling, tide, is indirect. The word comes to English direct from the Latin *aestuarium*, from *aestus* + *arium* (suff. = place of ________). *Aestuarium* in Roman times had two oceanographic meanings:

"1. Low ground covered by the sea at high water," and "2. A firth, creek, or part of the river up which a tide flows" (Simpson, 1960).

In French usage both meanings have persisted, the first, however, being restricted to broad embayments (*e.g.* Larousse, 1930): "Sinuosité du littoral, qui n'est couverte l'eau quá marée haute. 2. Golfe formé par l'embouchure d'un fleuve." (1. A curve of the shore which is not covered by water except at high tide. 2. A gulf formed by the mouth of a river.)

In English usage the first meaning has become very rare. Johnson (1773) defined estuary as "an arm of the sea; the mouth of a lake or river in which the tide reciprocates; a firth." Modern English usage may be indicated by quotations from standard dictionaries and encyclopedias:

Oxford English Dictionary (1933): "1. *gen.* A tidal opening, an inlet or creek through which the tide enters; an arm of the sea indenting the land. Rare in modern use. 2. *spec.* The tidal mouth of a great river, where the tide meets the current of fresh water."

Webster's Third International Dictionary (1961): "*1a:* A water passage (as the mouth of a river) where the tide meets the current of a stream; tidal river. B: An arm of the sea at the lower end of a river. 2: A drowned river mouth caused by the sinking of the land near the coast."

New International Encyclopedia (1915): "The widened channel at the mouth of a river in which there is a marked tidal action. An estuary is usually formed by submergence or drowning of the river valley which is then subjected to the erosive action of tides and waves."

Encyclopedia Britannica (1962): "The mouth of a river where sea and fresh water meet and where tidal effects are conspicuous. An estuary may result from the long-continued joint action of river and tidal erosion confined to a narrow structural depression, or it may be the drowned lower portion of a river valley."

Encylopedia Americana (1965): "When a shore line is sinking or has been recently depressed, rivers, unless large and heavily charged with sediments, have their valleys invaded by the encroaching sea, forming roughly funnel-shaped bays. Such bays are estuaries..."

Even excluding the first Larousse meaning of the intertidal zone of bays in general and the first Oxford and Johnsonian meaning of inlets not necessarily related to rivers, there is some disagreement among the several definitions. Tidal rivers, not involving submergence, would be excluded by the *Encyclopedia Americana*. Drowned valleys not subject to tidal action would be included only by Webster. Unfortunately the technical literature introduces even more inconsistencies.

Geomorphology

The earliest technical definition noted by the *Glossary of Geology and Related Sciences of the American Geological Institute* (Howell, 1939) is that of Lyell (1834): "Inlets of the land, which are entered by both rivers and the tides of the sea." This definition, like most of the common English ones, includes both a restriction to inlets of some sort and a relation to rivers, as well as the tidal action indicated by the etymology. Both the AGI Glossary and the oceanographic glossary of Hunt and Groves (1965) quote two Beach Erosion Board (1964) definitions: "1. That portion of a stream influenced by the tide of the body of water into which it flows; 2. a bay, as the mouth of a river, where the tide meets the river current."

The AGI Glossary (Howell, 1939) also quotes the *New International Encyclopedia's* (1915) definition (see above), which like one in *Himus's Dictionary of Geology* recognizes that the widened mouth of a river commonly results from submergence. The application of the term is restricted to the "drowned" valley of a river in the definitions of Finch and Trewartha (1942), as that of the *Encyclopedia Americana* and Webster's second definition cited earlier.

Pritchard (1967), Russell (1967), and others include fiords as estuaries.

Caspers (1967) and Morgan (1967) include deltapasses as estuaries, although Guilcher (1963) specifically excludes delta features. De Lapparent (1900) distinguishes an estuary from the delta that may fill it, and Russell (1967) and Steers (1967) point out the difficulty of making a distinction between other types of rivermouth estuaries and delta passes. The Bowden (1967) requires only that there is "an inflow of fresh water from land drainage," which presumably might include inflow from fresh-water springs. The 1960 Supplement to the AGI Glossary (Weller, 1960) includes not only "the lower courses of river and small streams (but) drainageways that lead seawater into and out of coastal swamps," returning to the first outmoded definitions of Johnson and the Oxford Dictionary.

Some definitions, such as the general one in the Oxford Dictionary, emphasize the inlet or embayment characteristic without specific restriction to river mouths. Emery and Stevenson (1957) and Russell (1967) regard lagoons and estuaries as a continuous series whose end members alone may be distinguished, but Pritchard (1967) describes bar-built estuaries (lagoons) as a type of estuary. Hedgpeth (1967) considers even a hypersaline lagoon as an estuary, although this would not be included in any common definition. Both Pritchard (1967) and Russell (1967) consider embayments of tectonic origin as types of estuaries regardless of the entry of fresh water required by the *Encyclopedia Britannica* for such embayments.

Ketchum (1951) would include as an estuary any body of water in which river and sea water are mixed, even the open coast, although the open coast is excluded implicitly by common definitions and explicitly by Pritchard (1967).

Hydrodynamics

Almost universally, authors have respected the tidal behavior referred to by the etymology of the term estuary. Russell (1967) explicitly excludes inlets of non-tidal seas, and Pritchard (1967) requires that there be a "free" connection between an estuary and the sea and specifically excludes inlets and lagoons whose communication with the sea is only at high tide. However, Ketchum's (1951) definition, based solely on the dilution of sea water by fresh water, would not exclude inlets of non-tidal seas, and Day (1964) includes "blind" estuaries which are cut off from the sea by bars.

Lee (1840), quoted by the AGI Glossary (Howell, 1939), Defant (1958), and Ippen and Harleman (1966) would include the limits of an estuary, the entire length of a river channel affected by tidal oscillations. A possible more seaward limit to the upper end of the estuarine part of a river mouth might be the limit to which the tides normally cause reversals of flow rather tahn merely increases and decreases in the velocity of seaward flow. This limit seems not to be used by any authors, although the limit of penetration of salt water, still farther seaward, is used by some (see next section).

A circulation system in which there is a net landward flow of sea water resulting from entrainment in seaward-flowing overlying fresh water, which typically develops in those estuaries in which the fresh-water flow is sufficiently large to maintain a two-layer system (Tully, 1958, Bowden, 1967), has been referred to as an estuarine circulation system, even when recognized in so large a body as the subarctic Pacific (Tully and Barber, 1961). An estuarine circulation system is not established in estuaries without significant vertical salinity gradients, and few authors would consider extension of the term, estuary, to cover the large bodies showing such circulation systems. Such an extension is excluded by Pritchard (1967).

Chemistry

For some authors, notably Ketchum (1951), the dilution of sea water by land drainage is all that is required for definition of an estuary. Most have additional geomorphic or hydraulic criteria, as previously discussed, and for some sea-water dilution is not required.

Among those who have sea-water dilution as a necessary but insufficient criterion, there is some variety in definition of the limits of the estuary with respect to the loci of various mixing processes. Mill (1924) considers that only the landward half of the Firth of Forth, in which there exists a distinctive halocline, is a true estuary. The seaward half, in which the salinity is somewhat less than that of the sea and increases gradually seaward, but in which the vertical salinity gradients are negligible, is not. Pritchard (1967) considers that the landward limit of an estuary is the limit to which some significant salinity extends. The adoption of these limits would restrict estuaries to those areas in which "estuarine circulation," defined in the previous section, occurs. However, those who would define an estuary on the basis of its geomorphology and tidal behavior would consider that the entire Firth and Forth is an estuary, that the landward limit of an estuary is the limit of significant tidal action, and that the term, estuaries, includes those inlets in which vertical mixing is sufficiently great to result in essential isohalinity in the vertical throughout.

Pritchard originally considered in 1952, that included among estuaries might be semi-enclosed coastal bodies in which the inflow of fresh water was less than the evaporation and, hence, in which the water that mixes with the sea water is more saline than the sea water. Pritchard called such estuaries inverse or negative estuaries. (Hedgpeth refers to a lagoon in which this condition exists as a hypersaline estuary.) Now however, Pritchard (1967) restricts the term estuary to those bodies in which freshwater inflow predominates over evapotranspiration.

National Estuarine Pollution Study Definition

The term estuary is defined for the National Estuarine Pollution Study by Title II, section 5, subsection (g)(5) of the Clean Water Restoration Act of 1966, Pl 89-753, amending the Federal Water Pollution Control Act (33 U. S. C. 4666 *et seq.*): "The term 'estuary' means all or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connection with open sea and within which sea water is measurably diluted with fresh water derived from land drainage."

Usage Appropriate in Hawaii

For the purpose of the Hawaiian study, it seems best to include as estuaries both drowned river valleys, such as Nawiliwili Bay on Kauai, and perennial, tide-affected river mouths, such as that of the Wailua River on Kauai. These are equivalent, respectively, to the second and first of the definitions of the Beach Erosion Board (1964). Generally the landward ends of drowned valleys in Hawaii have been filled with sediments, across which the rivers enter the bays. The actual mouths of the rivers are usually restricted by sand bars. The water of many of the drowned-valley bays is essentially sea water except during floods, and the water of many of the tidal rivers is essentially fresh, especially inland toward the limit of the tide. However, typical estuarine salinity and circulation patterns both exist in some of the drowned-valley bays and some of the tidal rivers, and the distinctions in both types between examples with these typical patterns and those without would be quite arbitrary.

The drowned-valley bays range from deep inlets to shallow indentations. The former are sufficiently enclosed to be estuaries, the latter are surely not, but the choice of a minimum bay-length mouth-width to serve as the criterion of an estuary is arbitrary.

The river mouths range from those of perennial streams with large discharges slightly restricted by bars, to those of intermittent streams cut off from the sea except during floods. Only those normally open qualify as true estuaries. Those normally closed may conveniently be called intermittent estuaries (blind estuaries, Day, 1951).

Although Pritchard (1967) equated drowned-valley estuaries and coastal plain estuaries, most of the drowned valleys in Hawaii were cut into the bedrock of the volcanic shields and the estuaries in them are bounded laterally by high ridges of lava rather than coastal-plain sediments. Pearl Harbor, Oahu, however, is a true coastal-plain estuary, occupying a drowned valley eroded into sediments.

Although the fresh water discharge from the major rivers inhibits the growth of corals, some of the drowned-valley estuaries have partial coral-reef bottoms and many have slight restrictions of their mouths by fringing reefs. An example is Kahana Bay, Oahu.

Kaneohe Bay, Oahu is unique, being the result of the coalescence of several drowned valleys and being effectively isolated from ocean waves by an extensive coral reef. It is, therefore, a lagoon as well as an estuary.

There are no fiords in Hawaii, and no semi-enclosed bays of tectonic origin.

Some coastal spring channels raise problems. The Wailuku River, entering Hilo Bay, is clearly an estuary being tidal, brackish, and of increasing salinity seaward throughout the half mile in which it has perennial flow due to spring discharge. The Keaukaha springs, also in Hilo, are identical in tidal response, fresh water supply, and mixing conditions, but they discharge through the irregular terrain of a fresh pahoehoe lava flow rather than a channel partly confined by sediments. Probably their channels too should be considered as estuaries. In conclusion, it appears that a compound definition of estuary appropriate to Hawaiian needs may be:

1. A bay, such as a drowned river valley, that receives fresh water diacharged from the land.

2. The tidal portion of the mouth of a stream.

This compound definition, similar to that of the Beach Erosion Board (1964), is slightly more inclusive than that of the National Estuarine Pollution study in that it does not require navigability (although a skiff could navigate all but the shallowest and narrowest of estuaries included) and in that it includes those drowned valleys or seaward parts of drowned valleys whose waters are not measurably diluted by fresh water.

Contract no. 19-12-446 of the Federal Water Pollution Control Administration with the University of Hawaii, 29 June 1968, for the *Study of Estuarine Pollution in the State of Hawaii*, specifies that the study shall include the following five major estuaries:

Kahului Harbor, Maui
Hilo Bay, Hawaii
Nawiliwili Bay, Kauai
Pearl Harbor, Oahu
Kaneohe Bay, Oahu

Of these five, Nawiliwili, Pearl Harbor, and Kaneohe clearly qualify as natural estuaries according to the definition suggested. It is questionable whether any part of Hilo Bay would have qualified prior to construction of the breakwater, although the degree of its enclosure by the natural reef and the quantity of fresh water supplied by the Wailuku and Wailoa Rivers might have been sufficient. The mouths of the two rivers are clearly estuaries. The additional restriction and confinement of mixing afforded by the breakwater should now be sufficient to qualify Hilo Harbor as an estuary. Kahului Harbor may well not qualify, even with its breakwaters, owing to an insufficient fresh-water supply. It is entered by no streams or significant springs but only storm drain discharge. It will, in spite of this, be included in the FWPCA sponsored study.

BIBLIOGRAPHY

Beach Erosion Board. 1961. In *Shore Protection, Planning and Design*, rev. ed. Appendix A, Glossary of Terms. Beach Erosion Board. Technical Report 4.

Bowden, K. F. 1967. Circulation and Diffusion. In *Estuaries*. Ed. by G. H. Lauff. Amer. Assn. Adv. Sci. Publ. 83:15-17.

Bowden, K. F. 1967. Estuaries. *In International Dictionary of Geophysics, I.* Ed. by S. K. Runkorn. :505.

Caspers, H. 1967. Estuaries: Analysis of Definitions and Biological Considerations. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:6-8.

Day, J. H. 1951. *The Ecology of South African Estuaries. I. A. Review of Estuarine Conditions in General.* Trans. Roy. Soc. S. Africa. 33:53-91.

Defant, A. 1958. *Ebb and Flow.* University of Michigan. Ann Arbor. :95.

Emery, K. O. and R. E. Stevenson. 1957. Estuaries and Lagoons. I. Physical and Chemical Characteristics. *In Treatise on Marine Ecology and Paleoecology, I.* Ed. by J. W. Hedgpeth. Geol. Soc. Amer., Mem. 67:673-693.

Encyclopedia Americana. 1965. Estuary. 1965 Ed. :527.

Encyclopedia Britannica. 1962. Estuary. 1962 Ed. 10:527.

Finch, V. C. and G. T. Trewartha. 1942. *Elements of Geography,* 2nd Ed. McGraw-Hill. :389.

Guilcher, A. 1963. Estuaries, Deltas, Slope in the Sea. *Interscience.* Ed. by M. N. Hill. New York. 3:620-624.

Hedgpeth, J. W. 1967. Ecological Aspects of the Laguna Madre, a Hypersaline Estuary. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:408-419.

Hedgpeth, J. W. 1957. Estuaries and Lagoons. II. Biological Aspects. *In Ecology and Peleoecology I.* Ed. by J. W. Hedgpeth. Geol. Soc. Amer., Mem. 67:693-729.

Himus, G. W. 1954. *A Dictionary of Geology.* Penguin. :49.

Howell, J. V. (Coordinating Chairman) and others. 1939. *Glossary of Geology and Related Sciences.* Amer. Geol. Inst. :325.

Hunt, L. M. and D. G. Groves. 1965. *A Glossary of Ocean Science and Undersea Technology Terms.* Compass, Arlington, Va. :43.

Ippen, A. T. and A. F. Harleman. 1966. Tidal Dynamics in Estuaries. *In Estuary and Coastline Hydrodynamics.* Ed. by A. T. Ippen. McGraw-Hill. :493-545.

Johnson, Samuel. 1773. *Dictionary of the English Language,* 4th Ed. London.

Ketchum, B. H. 1951. The Flushing of Tidal Estuaries. *Sewage Ind. Wastes.* 23:198-209.

Lapparent, A. de. 1900. *Traité de Geologie,* 4th Ed. Masson, Paris. 1:217.

Larousse. 1930. *Larousse des XXe Siecle.* Libraire Larousse Paris. 3:297.

Lee, C. A. 1840. *Elements of Geology.* New York. :379.

Lyell, Charles. 1834. *Principles of Geology,* 3rd Ed. London. 1:323.

Mill, H. R. 1924. *The Realm of Nature,* 3rd Ed. John Murray. London. :186.

Morgan, J. P. 1967. Ephemeral estuaries of the deltaic environment. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:115-120.

New International Encyclopedia. 1930. 2nd. Ed. Dodd, Mead & Co. New York. 8:115.

Oxford English Dictionary. 1933. Clarenden Press. Oxford. :300.

Pritchard, D. W. 1952a. Salinity Distribution and Circulation in the Chesapeake Bay Estuarine System. *Jour. Marine Res.* 11:106-123.

Pritchard, D. W. 1952b. A Review of Estuarine Hydrography. *In Advances in Geophysics, 1.* Ed. by H. E. Landberg. Academic Press. New York. :243-280.

Pritchard, D. W. 1967. What is an Estuary. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:3-5.

Russell, R. J. 1967. Origins of Estuaries. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:93-99.

Simpson, D. P. (Ed.). 1960. *Casell's New Latin Dictionary.* Funk & Wagnalls. New York. :28.

Steers, J. A. 1967. Geomorphology and Coastal Processes. *In Estuaries.* Ed. by G. H. Lauff. Amer. Assn. Adv. Sci., Publ. 83:100-107.

Tully, J. P. 1958. On Structure, Entrainment, and Transport in Estuarine Embayments. *Jour. Marine Res.* 17:523-535.

Tully, J. P. and F. G. Barber. 1961. An Estuarine Model of the Sub-Arctic Pacific Ocean. *In Oceanography.* Ed. by M. Sears. Amer. Assn. Adv. Sci., Publ. 67:425-454.

Webster's Third International Dictionary. 1961. Merriam. Springfield, Mass. :779.

Weller, J. M. (Chairman) and others. 1960. *Supplement to the Glossary of Geology and Related Sciences.* American Geological Institute. :72.

ESTUARIES AND POTENTIAL ESTUARINE POLLUTION ON THE MAJOR HAWAIIAN ISLANDS

by

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INTRODUCTION

The study of estuarine pollution in the State of Hawaii involves great contrasts. Some estuaries are fed by streams draining land in near wilderness condition; the estuaries are little used; they are subject to rapid and efficient flushing, and the chemical and bacteriological quality of their water is as good as its sparkling appearance suggests. Other estuaries receive a combination of urban, domestic, industrial, and agricultural wastes; their flushing is restricted; and their waters have become objectionable with respect to color, odor, bacteriological quality, and chemical content.

Unfortunately, it is difficult to obtain definitive information on the pollution of either relatively unpolluted or relatively polluted estuaries in Hawaii. Pollution seems to have been either of little concern or considered beyond control. Because information on the actual nature and extent of pollution is scanty and incompletely collected, we present here for most estuaries, not indications of estuarine pollution itself, but the aspects of the useage of estuaries and the drainage basins tributary to them that introduce potentials of pollution of various sorts. The tables presented may be regarded as checklists of possible pollution, the actual existence and extent of which is subject to field confirmation. Some field data on actual levels of pollution have already been collected and are summarized for a few major estuaries.

In time remaining in this project, the collection and collation of existing data will be completed and the gaps in essential data will be identified. Identifiable trends will be noted and, so far as possible, the development or increase of problems will be forecast. Considering the inadequacies already apparent, the extent of confirmation of existing and potential pollution of most estuaries will be somewhat unsatisfactory, but the best possible outline will be drafted for further necessary studies where a basis cannot be laid for possible control measures.

LAND USE AND POTENTIAL POLLUTION

In order to identify elements of potential pollution, we have tabulated the various estuaries of the major islands together with various water-development and land-use factors that appear to have some importance either as sources of possible pollutants, limitations of pollution, or controls on the consequences of pollution. These factors are discussed very briefly below.

It should be noted that it would at present be premature to generalize on the overall importance of any land-use factors and for most estuaries we are as yet quite unable to evaluate their actual effects. However, the tables will not only serve as guides to the continuing work in the project but should be useful in other estuarine pollution investigation that may be in progress before final results are obtained.

For each land-use or water-development factor, the symbol used in the tables is indicated.

Water Development

	Symbols used in tables
Irrigation diversion: Water is diverted for irrigation without significant storage. The irrigation is often outside the drainage basin of the diversions. Low-water flows are greatly reduced or even eliminated. Flushing of stream-mouth estuaries may be greatly restricted. Stream-mouth sand bars may be more extensively developed than under natural conditions. Flood flows remain essentially unchanged, however.	*I*
Power diversion: Water is diverted for hydroelectric power development and returned to the same stream. Essentially no effect on estuarine conditions.	*E*
Storage: There is significant storage of water in the stream course together with diversion. Even flood flows are reduced.	*S*

Agricultural Development

Sugar cane cultivation: Possible source of enrichment in fertilizer components such as nitrates and potash, especially through ground water. Possible source of herbicides, although many such chemicals are found to be highly adsorbed and degraded in the soil. Accelerated sediment yield may result from loss of cover from harvest until the vegetative canopy closes in. Erosion is, however, limited by furrowing, especially in irrigated fields.	*S*
Pineapple cultivation: Possible source of enrichment in fertilizer components and herbicides, as in sugar cane cultivation. Accelerated sediment yield, although erosion is controlled by quasi-contour planting, grassed drainways, etc.	*P*
Taro cultivation: Probably minor pollution contributions.	*T*

	Symbols used in tables
Banana cultivation: Pollution importance unknown and probably minor.	*B*
Ranching: Probably minor pollution contribution where animal population concentration is small. Important source of bacterial pollution, nitrates, etc., where the concentration is high as in feed lots and dairy pens.	*R*
Miscellaneous: Pollution contribution depends on nature and concentration of use.	*M*

Industrial Development

Sugar factory: Possible source of mud from cane cleaner, cane trash from cane cleaner, excess bagasse, waste sugars and other soluble organics.	*S*
Pineapple cannery: Pineapple wastes, soluble organics including organic acids.	*P*
Petroleum refinery: Refinery wastes, sulfides and sulfates, phenols, caustics.	*R*
Thermal power plant: Heated water.	*E*
Quarry: Accelerated sediment yield.	*Q*
Miscellaneous	*M*

Urban Development

Sanitary-sewered urban areas on estuary or within two miles upstream on tributaries: Augmented flood discharges. Trash, detergents, pollutants from minor industry. Accelerated sediment production in new subdivisions. Nitrates, phosphates, bacterial contamination.	*S*
Urban areas served by cesspools and septic tank-drain field systems on estuary or within two miles upstream on tributary: Pollutants listed for sewered urban areas plus high nutrient concentrations and bacterial contamination from cesspool overflows or other inadequacies.	*C*

Estuary Development

Commercial or military harbor: Fuel oil and lubricating oil spills. Bilge discharges. Ship sewage. Miscellaneous industrial pollution. Cargo spills.	*H*
Small boat harbor: Small boat sewage. Miscellaneous trash.	*S*
Sewer outfall -- raw sewage: Raw sewage, bacterial contamination, organic wastes, high nutrient concentrations.	O_R

	Symbols used in tables
Sewer outfall -- primary treatment: Bacterial contamination, organic waste, high nutrient concentrations.	O_P
Sewer outfall -- secondary treatment: High nutrient concentrations.	O_S
Pond fishery	F_P
Bait fishing	F_B*
Shell-fishing	F_S*
Swimming, boating, and other recreational uses	R*

*Some fishing, swimming and boating are common in practically all Hawaiian estuaries. Only useages significantly more intensive than normal are indicated in tables.

ESTUARIES OF NIIHAU AND KAUAI

There are no significant estuaries on Niihau.

The significant estuaries on Kauai are identified in figure 1 and the factors of land use pertinent to their potential pollution are summarized in Table 1.

Nawiliwili Harbor

Nawiliwili Bay is a well developed bay estuary which serves as the principal harbor for Kauai. The Bay consists of the drowned valley of Huleia Stream and its tributaries. The lower part of Huleia Stream itself is a stream-mouth estuary, being tidal for two miles inland of its entrance into the Bay. Under natural conditions the stream mouth was partly cut off from the Bay by sand bars, but the breakwaters now protecting the harbor have so reduced wave conditions in the Bay that the bar has effectively been removed. A large fishpond, now in poor condition, on the side of the Huleia River is of archaeological importance, having been constructed by the Menehune (the little people) according to legend. The Bay also receives fresh water from Puali and Nawiliwili Streams, both of which have inconsequential estuarine lower reaches.

Large areas in the drainage basins of all three streams are in sugar cane fields of comparatively low relief and there is a large cattle ranch in the drainage basin of the Huleia River. The headwaters of the Nawiliwili and Puali Streams are in the flat-sloped post-erosional lava dome of Kilohana. The headwaters of the Huleia are in the extremely rugged Waialeale-Kawaikini mass of central Kauai. Irrigation water is diverted from all three streams.

The town of Lihue lies partly in the valley of Nawiliwili Stream and the sugar mill of Lihue Plantation Company lies in the valley about 1-1/2 miles from the harbor. Some millyard drainage as well as urban storm drainage undoubtedly occurs by way of this stream, but the cane-cleaner wash water is diverted for use in irrigation in fields farther north and wastes to the sea about a mile north of Ninini Point, the northern point of Nawiliwili Bay.

Nawiliwili Bay was early used as a harbor, but the present harbor development dates from the 1930's when an outer breakwater and inner seawall were constructed and the harbor was deepened by dredging. Additional dredging was done about 1958 to produce coral for use in road construction, and a large stockpile of coral rubble was left in the form of a promontory between the main harbor basin and the Puali Stream mouth. Bulk-sugar-handling facilities were installed about 1957.

The Kauai Surf, a major hotel complex, was constructed at Kalapaki Beach, on a northern arm of the Bay outside the sea wall, about 1962.

The town of Nawiliwili, located on the floor of Nawiliwili Valley and the ridge to the south, is mainly served by cesspools, but the Kauai Surf hotel complex has a sanitary sewer system with a secondary treatment plant from which the effluent passes to the beach at Kalapaki.

A substantial silt load, chemical and livestock wastes, cesspool seepage, and thermal waters were listed as possible pollutants of Nawiliwili Bay in the hearings on Water Pollution Control standards (Department of Health, 1967(a)). The silt load of the streams is not monitored. It seems unlikely that this load greatly exceeds natural levels, or that livestock wastes are significant. No factual evidence concerning cesspool seepage or other bacterial contamination has yet been located. The only source of high temperature water would appear to be the Lihue mill; its high temperature waste waters may not flow to the Bay at all, and in any case would seem likely to be effectively cooled in the surface flow between the mill and bay. Stray cane trash may possibly arrive at the Bay either by way of Nawiliwili stream or by long-shore drift from the outfall north of the Bay. The commercial harbor activities undoubtedly contribute some pollution, but levels are not known.

ESTUARIES OF OAHU

The significant estuaries on Oahu are identified in figure 2 and the factors of land use pertinent to their potential pollution are summarized in Table 2.

Pearl Harbor

Pearl Harbor is a true coastal plain estuary. Its three lochs represent the drowned valleys of three major streams which crossed the southern coastal plain of Oahu and united to form a single river flowing to the sea in the valley that is now flooded to form the main channel. The lochs have been considerably altered in shape by marine erosion and sedimentation. The geologic history of the harbor has been outlined in detail by Stearns and Vaksvik (1935).

The natural fresh surface-water supply of the harbor is derived from eight streams which represent tributaries of the original loch-valleys: Honouliuli and Waikele entering West Loch, Waiawa entering Middle Loch, and Waiau, Waimalu, Kalauao, Aiea, and Halawa entering East Loch. The low-water flows of all of these streams are diverted far inland for sugar-cane irrigation.

The discharges of these streams are supplemented by flows of four large springs representing the discharge of an immense fresh ground-water body floating on and displacing salt water in the lava-flow bedrock of the island (Visher and Mink, 1964). The springs emerge from the toes of bedrock ridges between the streams, where the coastal plain sediments have been stripped off or thinned by wave erosion. The Waikele Spring flows to West Loch, the Waiawa Springs to Middle Loch, and the Waiau and Kalauao Springs to East Loch.

Pearl Harbor became a United States naval base by treaty at the time of the Hawaiian Kingdom. It is the headquarters for the 14th Naval District, and includes the Pear Harbor Naval Shipyard. The harbor has been improved by dredging a number of times, notably in the 1930's. The peripheral lands have now mostly been acquired by the Navy although portions are under lease for sugar-cane cultivation and other uses.

There is a large number of fishponds around the margins of the harbor, and the harbor was once the site of intensive bait fishing. Oysters grow in the harbor but were never a source of much income.

Only very meager observations on currents in Pearl Harbor are available. As summarized by Laevastu and others (1964), there are weak reversing tidal components with velocities on the order of a few tenths of a knot at most superimposed on a prevailing seaward flow resulting from stream and spring flow and wind drag.

Pearl Harbor receives wastes from the ships in the harbor, the various naval installations, surrounding communities, a sugar mill at Waipahu, and a thermal power plant at Waiau. The Division of Sewers in "A Report on Sewerage Master Plan for Waipahu, Ewa, Oahu," (1957) lists 69 outfalls by actual count on the shorelines of East Loch and estimates that there are over 100 outfalls in total. Many of these outfalls carry sewage from naval installations. Sewage from the towns of Halawa, Aiea, and Pearl City is carried to treatment plants which discharge either into tributary streams or directly to the harbor itself. The Waipahu sugar mill waste is combined with sewage from the town of Waipahu to provide irrigation on the Waipio Peninsula between West Loch and Middle Loch. Some of this water eventually finds its way to the harbor.

Fresh water from the Waiau spring that is used for part of cooling in the Hawaiian Electric power plant at Waiau is pumped inland for irrigation, as is water from other springs, but discharges directly into the harbor in rainy periods. Salt water used for additional cooling in the power plant is discharged direct to the harbor.

Bacteriological sampling made in connection with a study of the oysters (Sparks, 1963) indicated that the coliform concentration of the water in West Loch ranged from 620 to 2,400,000 MPN/100 ml with a mean of about 180,000. The oysters themselves had coliform concentrations of 2,300 to 24,000,000 MPN/100 ml. The biological oxygen demand in Middle Loch was found by Austin Smith and Assoc. et. al. (1961) to vary systematically from 2.8 ppm near Ford Island to .02 ppm at the harbor entrance. The dissolved oxygen was found to vary between 5.2 ppm and 8.0 ppm but without apparent systematic geographic variation. The coliform concentration ranged from 62 to 70,000 MPN/100 ml.

Kaneohe Bay

Because the ecology and pollution of Kaneohe Bay are the subject of a comprehensive discussion in Part II of this report, no space will be given here to its description.

ESTUARIES OF MOLOKAI, LANAI, KAHOOLAWE, AND MAUI

Pelekunu Bay on the north coast of Molokai and Halawa Bay at the northeast end of the island are bay estuaries and Halawa Stream has a short estuarine lower reach. No pollution problems are known in these estuaries.

There are no significant estuaries on Lanai or Kahoolawe.

Significant estuaries of Maui are identified in figure 3 and factors of land use pertinent to their potential pollution are summarized in Table 3. Many bays on the north coast of Maui are the result of the drowning of very steep valleys. Most are very open and only a few of the better developed bay estuaries are tabulated.

Kahului Harbor

Neither Kahului Harbor nor the more inclusive Kahului Bay is a true estuary. The Bay is simply the reentrant on the north coast of the island of Maui between the slopes of the two volcanoes, Haleakala and West Maui, of which it is formed. The Harbor is simply that part of the head of the Bay which has been protected by breakwaters and improved by dredging. Kahului Harbor is included in the discussion here because it is the principal harbor of Maui and because it shares some pollution problems with some of the true Hawaiian estuaries.

No fresh-water streams or significant springs enter the harbor, although there must be some fresh-water seepage into the harbor from the basal ground-water body inland. Some storm drains enter the harbor, but the sanitary sewage of the nearby towns is disposed of into the Bay through two outfalls outside of the Harbor. The outfall servicing the town of Kahului empties into the Bay at the base of the east breakwater and the one serving the town of Wailuku empties into the Bay a quarter mile west of the west breakwater.

Wastes from the Maui Pineapple Company cannery are discharged through the two sanitary sewer outfalls, principally that servicing Wailuku.

The Maui Electric thermal power plant which is located near the base of the east breakwater draws salt water for cooling from wells and disposes of this water at the sea surface outside the Harbor.

Iao Stream, one of the major streams of West Maui discharges to the Bay three-quarters of a mile west of the west breakwater.

Herschler and Randolph (1962) found that the dissolved oxygen values in most samples of water from the bay equalled or exceeded the theoretical saturation point for sea water (6.7 ppm). The biological oxygen demand ranged from 0 to 32.00 ppm. In general, except near the outfalls, the biological oxygen demand was lower than the dissolved oxygen concentrations. The near-shore waters of the harbor were fresher (13.0 °/oo chlorinity) than the water nearer the breakwaters (18.50 °/oo chlorinity). Coliform concentrations indicated that the near-shore waters were bacteriologically safe, with coliform concentrations under 100 mpn/100 ml except occasionally between the piers. The other waters in the harbor were generally good. Very high coliform concentrations were found in the vicinity of the sewer outfalls. Coliform counts outside the breakwaters varied within wide limits (43 to 150,000 MPN/100.

A half mile east of the east breakwater is Kanaha Pond, a bird refuge occupies a series of depressions in the weathered Haleakala lavas. The pond, cut off from the sea by a beach ridge, is fed by surface drainage, partly from a dairy area and partly by ground water, and discharges by overflow of the beach ridge only during flood periods. A pollution problem is clearly indicated by the odor of the pond.

ESTUARIES OF HAWAII

Because most of the volcanoes that compose the island of Hawaii are so youthful, there are few estuaries. No perennial streams reach the coast for three-fifths of the distance around the island, and valley development is restricted mainly to the northeast coasts of the mountains of Mauna Kea and Kohala. Few of the valleys are drowned to form significant estuaries, but the major ones are identified in figure 4 and land-use factors pertinent to their potential pollution are summarized in Table 4.

Hilo Harbor

Neither Hilo Bay nor Hilo Harbor is a typical estuary. Hilo Bay is simply the coastal reentrant resulting from the joining of the slopes of the volcanoes of Mauna Kea, Mauna Loa, and Kilauea. The head of this Bay was naturally protected by the Blonde Reef (coral) on which a breakwater was erected between 1908 and 1930. The harbor has been the principal port of the island since the 19th century.

Fresh water enters Hilo Harbor by way of the Wailuku River which has a typical but very short estuarine lower reach, and the Wailoa River, which is a spring-fed channel. Additional fresh water is discharged to the sea east of the harbor by extensive springs at Keaukaha.

The city of Hilo is served partly by cesspools and partly by a sanitary sewer system which discharged raw sewage until recently into the middle of the harbor. In about mid-1966 a plant for secondary treatment was opened east of the breakwater with effluent discharge about half mile from shore in the open ocean. The cane cleaning plant at Hilo Sugar Company, which is located on the west side of the harbor, is the source of a great deal of muddy waste water and some cane trash and baggasse discharge. Efforts are made to haul the solid waste inland for disposal. At times the currents sweep this sugar mill waste water northward out of the Harbor and at other times southward into the Harbor.

A baggasse wall-board plant is located in the spring zone on the Wailoa River, but it has not been operated for several years.

In a study before the sewage treatment plant and the new outfall were constructed, Belt, Collins and Associates (1961) found that chlorinity in the bay varied between 10.7 $^{o}/oo$ and 16.0 $^{o}/oo$ while in Wailoa estuary the lowest value was 2.13 $^{o}/oo$. In the Bay, the dissolved-oxygen levels approached the point of near extinction (3.0 ppm) but in the Wailoa estuary the levels of dissolved oxygen were a little better (3.12 to 5.18 ppm). The biological oxygen demand was not ascertained. Coliform concentrations in the Bay were found to range from 62 to 240,000 MPN/100 ml; streptococci varied between 62 and 24,000 MPN/100 ml; and E. coli between 0 and 7,000 MPN/100 ml. Comparable analyses for the period since the new sewer outfall was put into operation do not appear to be available.

Table I. Estuaries of Kauai and their potential pollution

Estuary System	Bay Estuary	Stream Estuary	Water Develop- ment	Agricultural Development	Industrial Development	Urban Develop- ment	Estuary Development
Waimea		Waimea R	I, E	R, S, T		C	
Hanapepe		Hanapepe R	I	S, T, R		C	
(Port Allen)	Hanapepe B				I	C, S	H, [illegible] (O_p)[1]
Wahiawa	Wahiawa B	see footnote 2)	S	S, P			
Lawai	Lawai B	Lawai Str	I	S, R			
Nawiliwili		Huleia Str	I	S, R			I_P
	Nawiliwili B		I	S	S, W[3]	C, S	H, F, R, O
Hanamaulu		Hanamaulu Str	I	S		C	
(Ahukini)	Hanamaulu B						R
Wailua		Wailua R	I, E	S, R		C	S, R
Kapaa		Kapaa Cnl		S, P	P	C	
		Kapaa Str		S, P, R		C	
Anahola		Anahola R	I	S, R		C	
	Anahola B						R
Moloaa	Moloaa B	Moloaa Str	I	S, R			
Kilauea		Kilauea Str	I	S, P			
	Kilauea B				Q		
Kalihiwai		Kalihiwai Str	I	S, R			
	Kalihiwai B						R
Hanalei		Hanalei R	I	T, R			R
		Waioli Str		R			
		Waipa Str		R			
	Hanalei B					C	R, I_R
Lumahai		Lumahai R		R			
Wainiha		Wainiha R	I	R, T			
	Wainiha B					C	

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[1] The Eleele sewer outfall is outside the Port Allen breakwater.

[2] The former Wahiawa stream-mouth estuary is largely filled with sediments resulting from the collapse of a large hydraulic fill dam that was under construction in the mountains in the 1930's. The beach sand has a high content of terrestrial sediments and the water in the bay is also still muddy.

[3] The cane cleaner waste water from the Lihue mill is partly used for irrigation. Excess is disposed of to the open coast a mile or so north of Ninini Point at the northernmost point of Nawiliwili Bay.

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Table 2. Estuaries of Oahu and their potential pollution

Estuary System	Bay Estuary	Stream Estuary	Water Development	Agricultural Development	Industrial Development	Urban Development	Estuary Development
Pearl Harbor	Pearl Hbr		I	S, P, R	S, I, M	S	H, O_H, O_P, F_P, F_H
Keehi		Moanalua Str			M	S	
		Kalihi Str			M	S, C	
	Keehi Lgn				M		H, S, M
Honolulu		Kapalama Cnl			P, M	S, C	
		Nuuanu Str				S, C	
	Honolulu Hbr				M, R, C	S	H, $(O_P)^{1)}$
Ala Wai	Ala Wai Hbr	Ala Wai Cnl				S, C	S, P
Kuapa	Kuapa Pond					S, C	S, R
Kaelepulu		Kaelepulu Str				S, C	P, O_S
Kawainui		Kawainui Cnl		R		S, C	P, O_S
Kaneohe	Kaneohe B		I	B, R, M	M	S, C	S, R, F_H, F_S, F_P, O_P, O_S
Kahana		Kahana Str	I	S, R		C	R
	Kahana B						R
Waimea		Waimea R	I	S, R		C	
	Waimea B						R
Waialua		Loko Ea	I	S, R		C	F_P
		Anahulu R	I	S, R, P		C	
	Waialua B						S, R
Kaiaka	Kaiaka B	Paukauila Str	I	S, T, R, P		C	
		Kiikii Str	I	S, R, P		C	

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1) The outfall from the Honolulu sewer system discharges to the ocean off Sand Island rather than into the harbor.

Table 3. Estuaries of Maui and their potential pollution

Estuary System	Bay Estuary	Stream Estuary	Water Develop-ment	Agricultural Development	Industrial Development	Urban Develop-ment	Estuary Development
Honomanu	Honomanu B		I				
Makaiwa	Makaiwa B		I				
Waipio	Waipio B		I	R			
Hoolawa	Hoolawa B		I	R			
Pilale	Pilale B		I	R			
Kuiaha	Kuiaha B		I	R, P			
Maliko	Maliko B			S, P			
Kahului	Kanaha Pd			S, R			see footnote 1)
	Kahului Hbr			S	P, E, M	S, C	H, R, (O_P), (O_R)[2]
Kahakuloa	Kahakuloa B			R, T			
Honokohau	Honokohau B		I	P		C	
Honolua	Honolua B		I	P			R

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[1] Kanaha Pond is used as a wildlife sanctuary.

[2] The Wailuku sewer outfall (primary treatment) and Kahului sewer outfall (raw sewage) are in the ocean, respectively, west and east of the harbor.

Table 4. Estuaries of Hawaii and their potential pollution

Estuary System	Bay Estuary	Stream Estuary	Water Develop-ment	Agricultural Development	Industrial Development	Urban Develop-ment	Estuary Development
Hilo		Wailoa Str			M	C, S	S, R
		Wailuku Str	E	S	M	S, C	
	Hilo Hbr				S, M	S, C	H, R, (O_S)[1], F_R
Waipio		Waipio Str	I	S, T			
Waimanu		Waimanu Str	I				
Pololu		Pololu Str	I	S			

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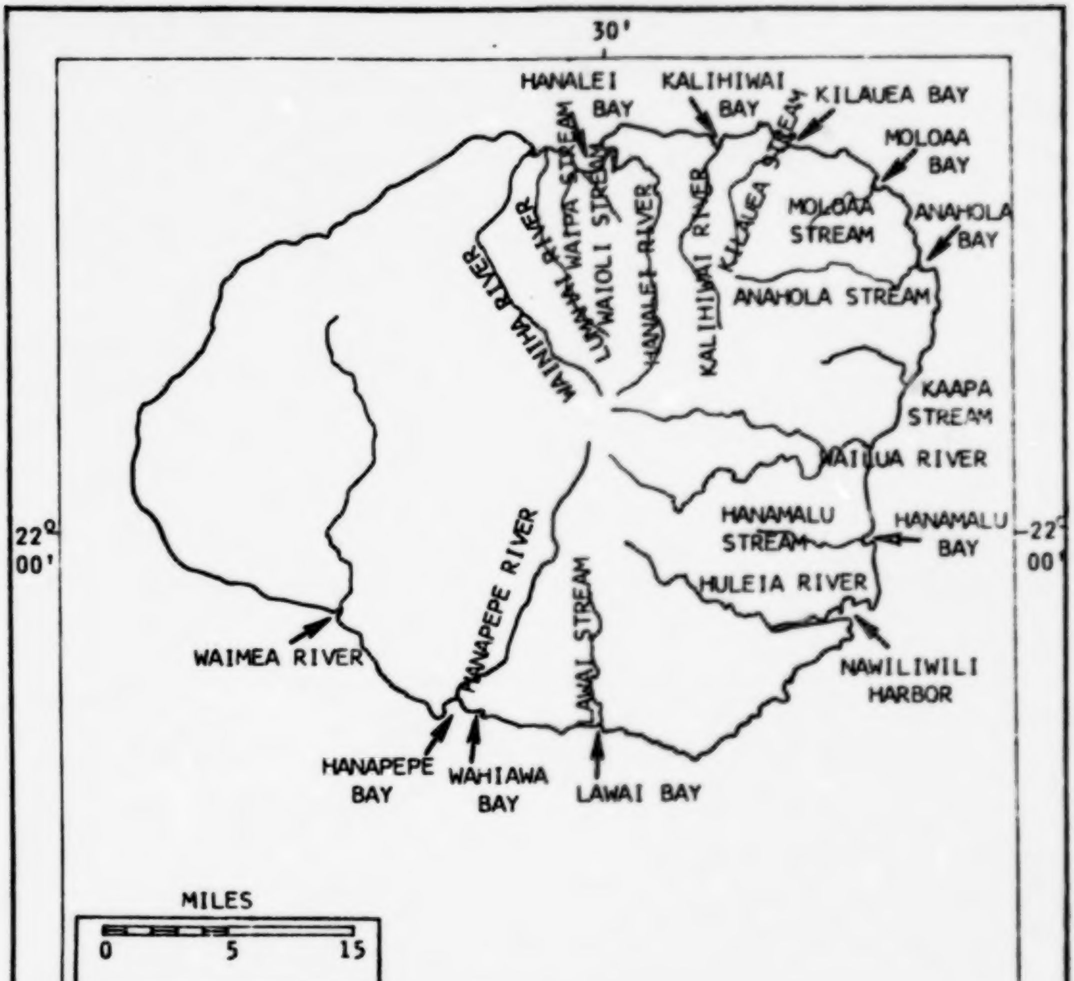
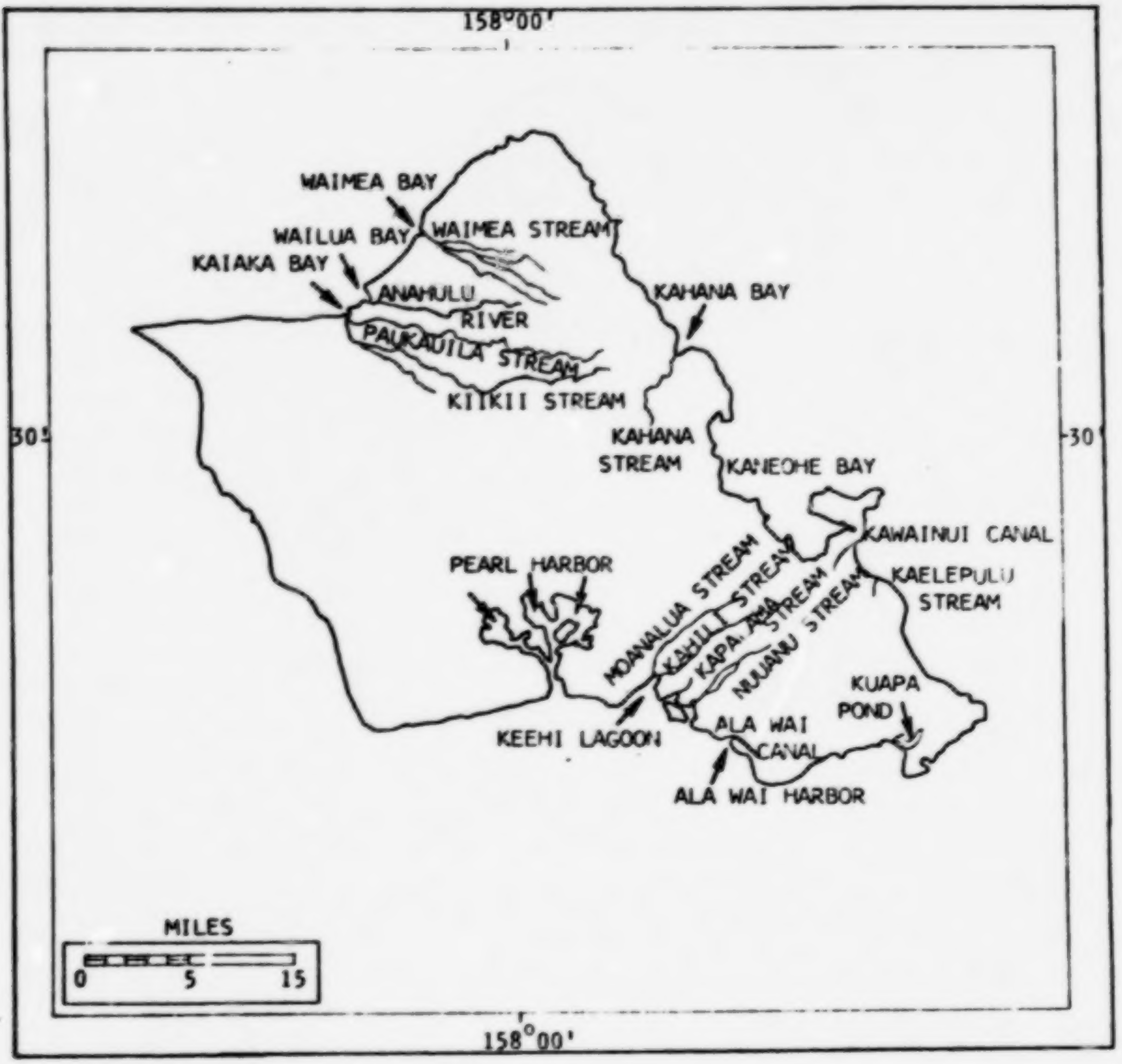
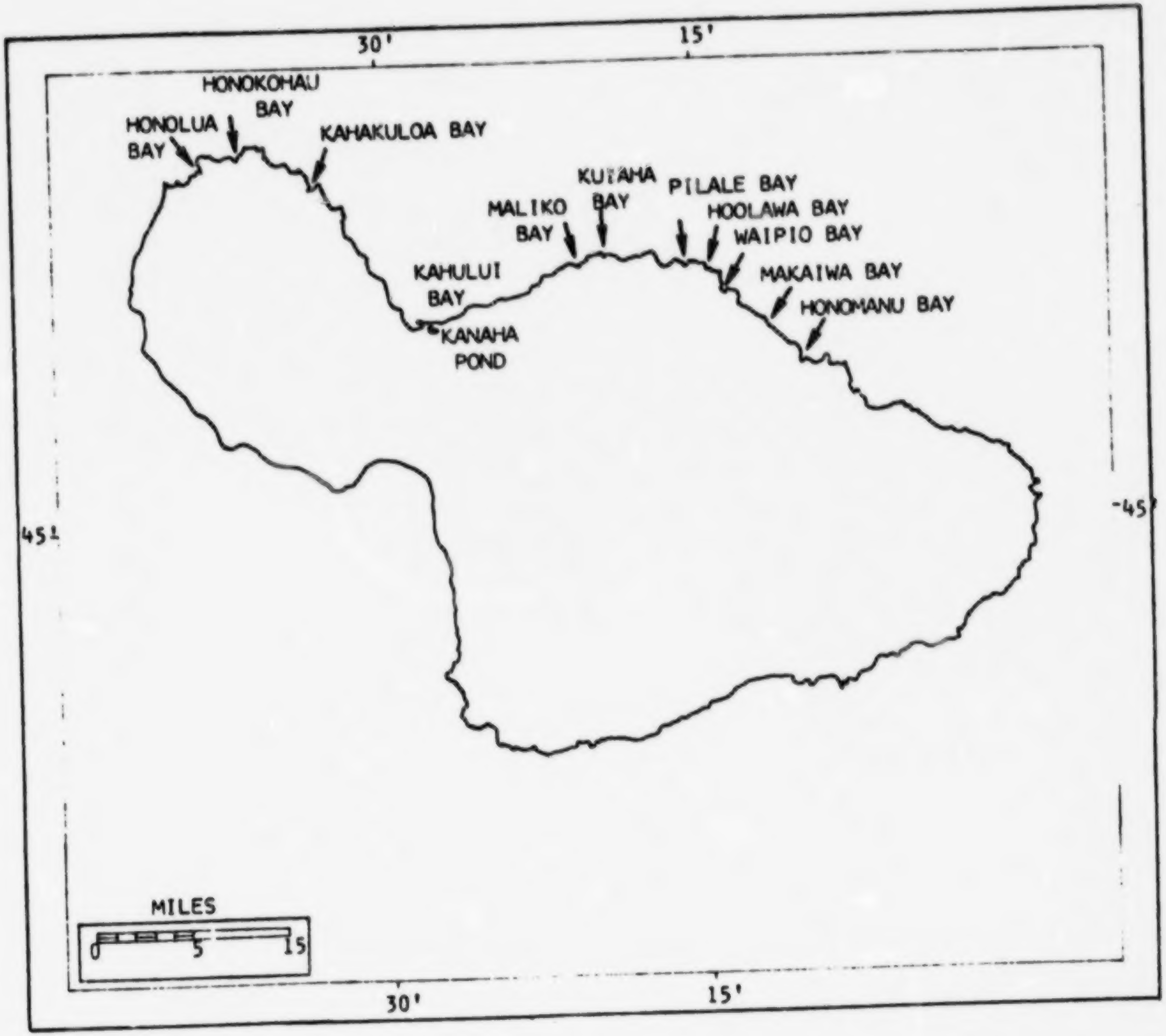
[1] The new Hilo sanitary sewer outfall is outside of the breakwater.



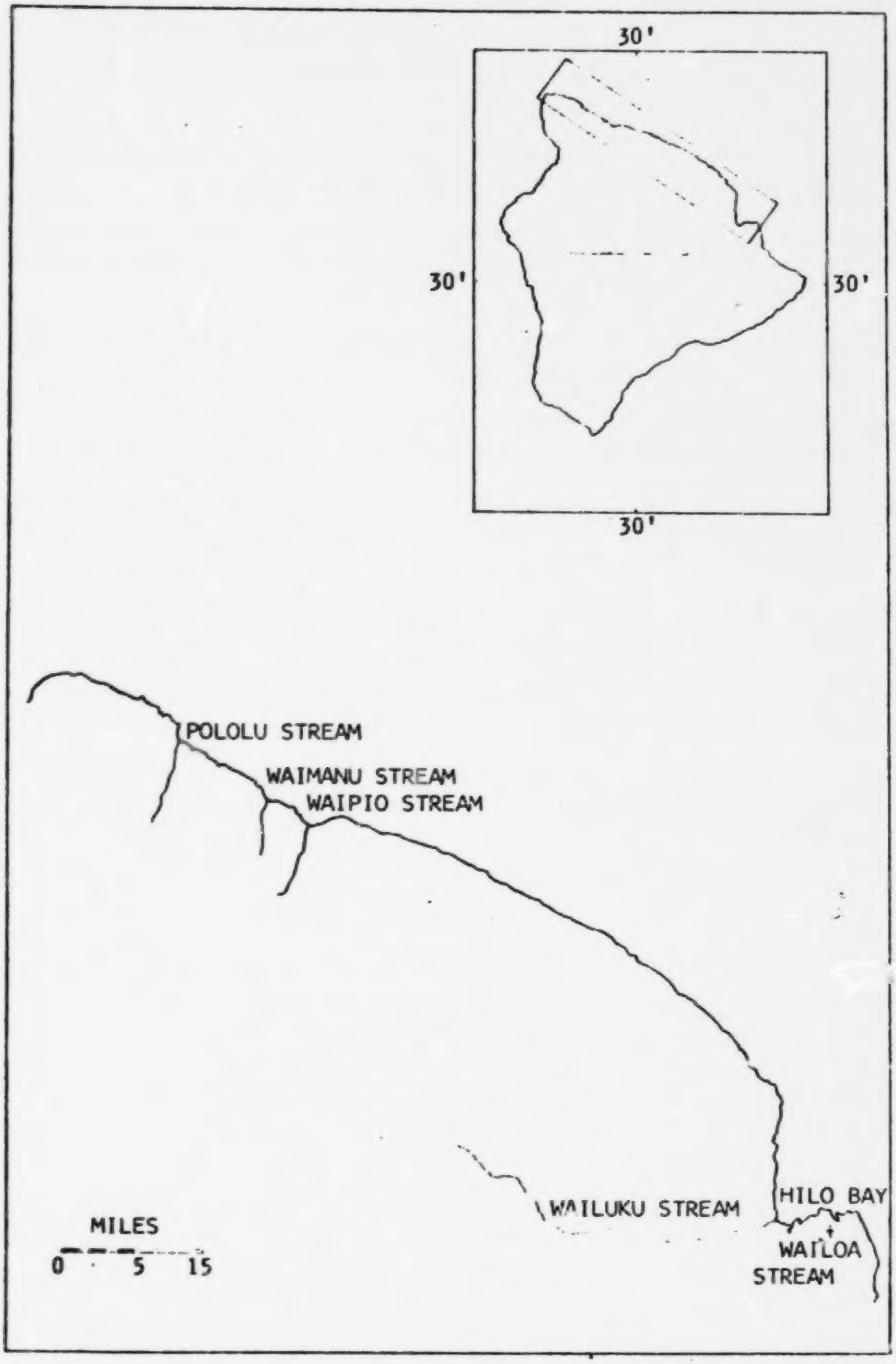
ESTUARIES FOR THE ISLAND OF KAUAI



ESTUARIES FOR THE ISLAND OF OAHU



ESTUARIES FOR THE ISLAND OF MAUI



ESTUARIES FOR THE ISLAND OF HAWAII

BIBLIOGRAPHY

Austin Smith and Associates and Metcalf and Eddy. 1961. *Final Report on Pearl City Treatment Plant.*

Belt, Collins and Associates, Ltd. 1961. *Hilo Sewer System Study,* Department of Public Works, Hilo, Hawaii.

Department of Health, State of Hawaii. 1967(a). *Public Hearing No. 1 & 2 on Water Uses and Standard of Water Quality for Kauai and Niihau Waters.*

Division of Sewers. 1957. *A Report on Sewerage Master Plan for Waipahu, Ewa, Oahu,* Department of Public Works.

Herschler and Randolph. 1962. *Study of Pollution in Kahului Bay, Maui, Hawaii,* Department of Health, State of Hawaii.

Laevastu, Taivo, Don E. Avery and Doak C. Cox. 1964. *Coastal Currents and Sewage Disposal in the Hawaiian Islands,* Hawaii Institute of Geophysics, University of Hawaii.

Sparks, A. K. 1963. *Survey of the Oyster Potential of Hawaii,* Hawaii Division of Fish and GAme.

Stearns, H. T. and K. N. Vaksvik. 1935. *Geology and Groundwater Resources of the Island of Oahu, Hawaii.*

Visher, F. N. and J. F. Mink. 1964. *Ground-Water Resources in Southern Oahu, Hawaii,* U.S. Geological Survey Water Supply Paper 1778.

PART II. KANEOHE STUDY

SANITARY QUALITY

by

Nathan C. Burbank, Jr.

Kaneohe Bay, Oahu represents possibly the finest large bay on the island of Oahu. It, by virtue of its shallow character, offers an ideal area for recreation, in particular, boating, fishing, and water-contact sports. It is a fishing area for minor sport fishing and the only source of salt water clams on Oahu.

The surrounding land area, because of its close location to metropolitan Honolulu, serves as a suburb to house many of the people who work in the Honolulu city center.

Kaneohe Bay is located on the northeastern coast of Oahu. It lies in a general northwest to southeast direction from 21°31'N 157°51'W to 21°21'N 57°48'W. The dimensions of the Bay are approximately 8 miles long and 2.6 miles wide, covering an area of approximately 11,360 acres at mean sea level.

An extensive shoal barrier reef, sand, and coral rubble front the bay from the ocean with channels leading directly into the Bay on either side of this shoal area. The northeastern channel is approximately 34 feet deep while the southern channel is approximately 10 feet deep. The ships' channel, which is within the Bay and parallel to the coastline averages 40 feet deep.

The southeastern portion of the Bay is relatively an isolated basin. It is separated from the other parts of the Bay to the west by Coconut Island and the southeastern section by the fronting shoal areas. The basin to the north is bordered by the southern shore of Mokapu Peninsula which is occupied by the Kaneohe Marine Corps Air Station. The eastern side of the basin is bordered by an extensive coral shoal area. Three streams, Keaahala, Kaneohe, and Kawa empty into the southern portion of the Bay. The drainage areas of this shoreline contain most of the population of the entire coastline of the bay.

Of the total surface area of the Bay, the southeastern portion contains 19.9% or approximately 2200 acres. In addition to the surface run-off from the three streams, the Bay receives raw sewage discharged from Coconut Island, the Hawaii Institute of Marine Biology (HIMB), and treated sewage from two larger plants near the south and north shores of the coastline. The Kaneohe municipal sewage treatment plant discharges an average of 2.1 million gallons per day of sewage which has received secondary treatment plus chlorination and the Kaneohe Marine Corps Air Station discharges an average of 0.8 million gallons per day of primary treated waste chlorinated before discharge.

Raw sewage is discharged from Coconut Island and HMBS in the amount of 20,000 gallons per day into the ships' channel at the northeastern section of the coral reef fringing Coconut Island.

The rainfall pattern in the Kaneohe Bay area is typical of those of the Hawaiian islands. The weather is influenced by two physical factors, the trade winds and the topographic features of the islands.

In summer the rainfall increases rapidly from the northeastern shores to the mountain tops. This is due to the steep mountain slopes forcing the trade winds to rise. The elevation to which clouds can rise is limited by temperature inversion, which is characteristic of the trade winds. The Kaneohe region exhibits this characteristic.

The winter rainfall patterns are similar to those in the summer except that they are interrupted by periods of southerly storm rainfall, caused by occasional cyclonic storm patterns. These storms often provide unusually heavy rainfall in this area.

The median annual rainfall based on twenty years of observation in the Kaneohe area ranges from 40 inches along the southern portion of Mokapu Peninsula to 50 inches over Kaneohe and Keaahala Stream mouths. The rainfall on top of the Koolau Mountain range varies from 75 inches over the drainage areas emptying into the southeastern portion of the Bay to 250 inches over drainage areas emptying into the northwestern portion of the Bay. The wet season occurs from October to April and the dry season from May to September.

Stream discharge. The three streams, Kawa, Kaneohe, and Keaahala,empty into the southeast basin of the Kaneohe Bay drainage area of approximately 13 square miles and contribute approximately 50% of the total surface run-off into the Bay. The peak discharges of two streams Kamooali and Keaahala were recorded as 6610 and 2750 feet per second (cfs) in October 1958 and May 1965.

For the purposes of this study selected parameters of sanitary significance were observed at 9 sampling stations in the bay representing areas influenced by the streams, the sewage treatment plants, Coconut Island (the site of the HMBS), and the ships' channel. These are clearly designated on the map of the area along with the water quality standards set for the waters, AA for Marine research and shellfish propagation, A for water sports recreation and esthetic preservation, and B for small boat harbors.

Samples were collected from the respective streams and the sites in the southeastern portion of the bay at regular intervals at three depths, surface, mid-depth, and bottom. The survey covered a period when all tidal variations were observed.

The analytical procedures involved measurements of transparency, bacteriological evaluation (Most Probable Number of *Coliforms* and *fecal streptococci*), dissolved oxygen, temperature, chlorinity, pH, and nutrients (in particular, nitrates and phosphates). During a three-month period wet season, observations of these parameters at the sampling sites showed that high rainfall accompanied by subsequent high surface run-off trigger extreme variations in the physical and chemical characteristics of water quality in the streams and the nearshore waters of Kaneohe Bay.

The silt load associated with high surface run-off is plainly obvious at the stream mouths and in the nearshore waters in the Bay reducing the transparency of the waters materially.

The density of *fecal streptococci* in the stream and nearshore waters follows the pattern of streamflow, being particularly high in the lower reaches of the stream, immediately beyond the stream mouths, and in the shallow waters overlying the clam beds following heavy rains.

The high run-off is responsible for a high dilution effect upon the natural chlorinity concentration of the Bay and is also responsible for high concentrations of nitrate-nitrogen in these waters. Further, the high surface run-off also lowers the water temperature of the surface waters along the southshore areas of the Bay.

The dissolved oxygen content of the Bay water is not appreciably affected by high run-off. However, in certain areas organic matter discharged by the stream may be deposited in the lower reaches of the stream and the Bay and this demand reduces the oxygen tension in the Bay below the limits set for the Bay as a receiving body of water.

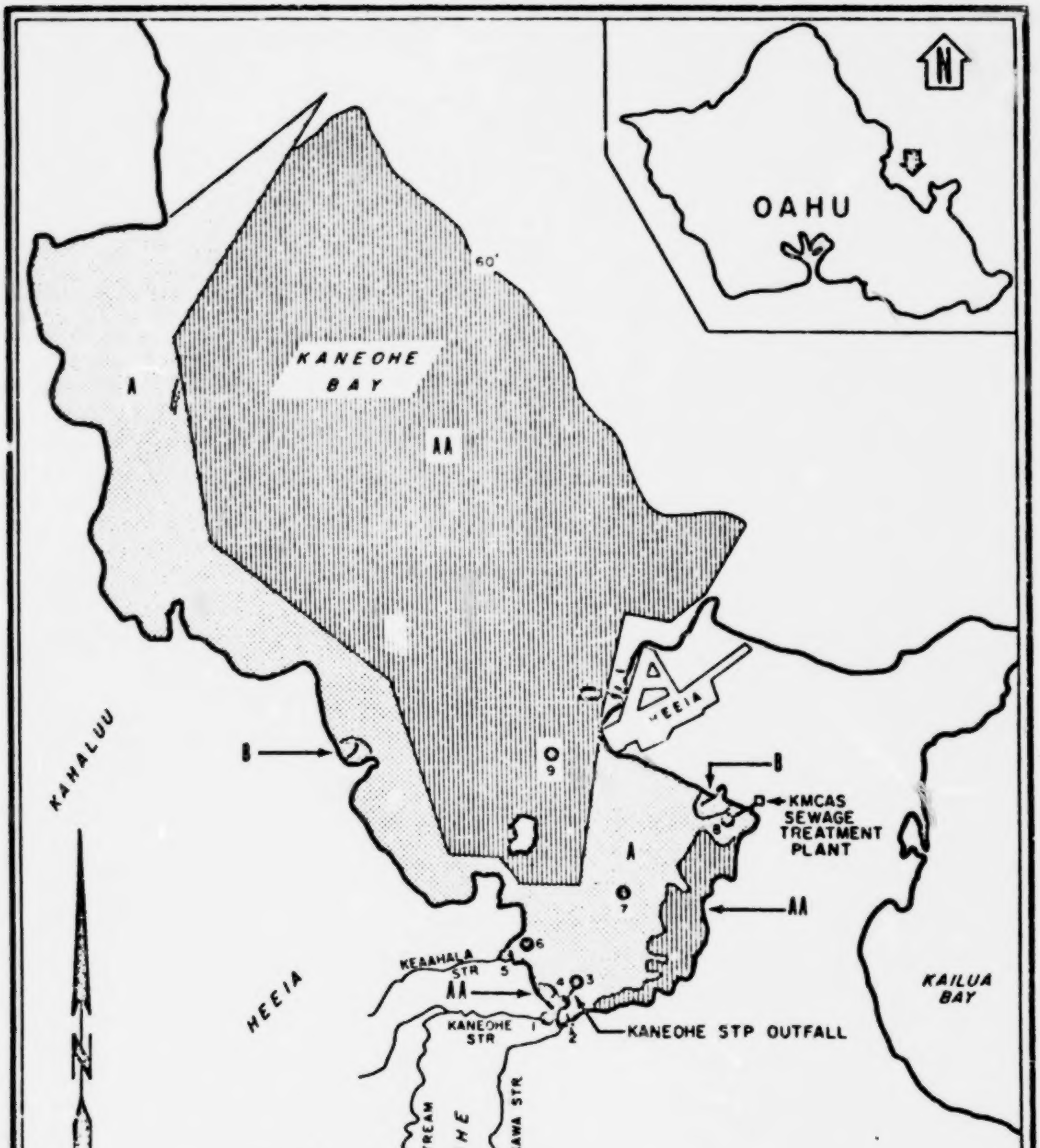
The nutrient load in periods of low discharge of the streams appears to stimulate phytoplankton to produce supersaturated oxygen conditions.

pH remained stable at all locations; it does not appear to be affected by the amount of streamflow entering the Bay nor does it vary within the Bay.

Phosphate concentrations appear to be directly related to the rate of discharge from the sewage treatment plants. Phosphate did not increase significantly from surface run-off. Only when the Kaneohe Sewage Treatment Plant discharged into the Bay in excess of 3 MGD flows did the phosphate-phosphorus concentration exceed the values set for class A water (less than

0.020 mg/l as total P).

During wet weather flows, nitrate-nitrogen exceeded the level of the standards for class A waters in the streams and in nearshore waters (less than 0.10 mg/l as total N).



SAMPLES SITES IN KANEOHE BAY

Reproduced from best available copy.

MINERALIZATION

by

Kaare R. Gundersen

Sampling and Analysis

In the period 31 July to 21 November a total of 9 regular samplings (Fig. 1) have been made at stations 1, 2, 8, 9, and 10. Two analyses made at stations 3, 4, 5, 6, and 7 in July and August showed absence of bacteria of fecal origin at all depths. Samplings at these stations were therefore temporarily suspended, but will be resumed during the winter season.

Analytical procedures for fecal coliform bacteria and enterococci were made according to standard methods described in Millipore Filter Corp.'s Manual (ADM40, 1965), *Techniques for Microbiological Analysis*. Total bacterial counts were made by Millipore filtration after dilution of samples. Colonies were developed on Marine Agar (Difco). After 24 hours of aerobic incubation at 25°C bacterial counts were made. All analyses were made in duplicate.

In addition to the regular monitoring of Kaneohe Bay, several other samplings have been made in connection with studies of nitrification, mineralization, and distribution of anaerobic bacteria.

Both of the sewage treatment plants affecting the Bay have been visited once and bacteriological analysis made of ingoing sewage and effluent.

Results and Preliminary Conclusions

A. *Fecal coliform bacteria* (Fig. 2A, Table 1). High counts have consistently been recorded in the KMCAS sewage outfall area (station 8). The highest count, 543,000/100 ml, was recorded on September 26 in surface water. There was a significant difference between the counts in surface water and in water collected at a 1-m depth in 7 out of 9 samplings. Fecal coliforms have been found at the sewage outfall from the municipal plant (station 10) and at other stations situated in the SE sector of the Bay (station 1, 2, and 9) but in relatively low numbers. These bacteria are, however, absent in the middle and northern sectors (stations 3, 4, and 5) and in the ocean (stations 6 and 7).

B. *Enterococci* (Fig. 2B, Table 2). The distribution of enterococci shows the same general picture as the fecal coliforms: high counts at the KMCAS sewage outfall and occasional appearance in the SE sector. The highest individual count, 6950 bacteria/100 ml, was recorded in surface water at station 8 on October 10.

C. *Total bacterial counts* (Fig. 2C, Table 3). The overall average of heterotrophic bacteria, capable of growth in a sea-water medium, in Kaneohe Bay is approximately 45 x 10^4/100 ml with a fairly uniform distribution. The only area which significantly exceeds this average is the area of the municipal sewage plant outfall (station 10). The highest individual count at this station was recorded at a 1-m depth on September 11, *viz.*, 1170 x 10^4 bacteria/100 ml. This distribution pattern of bacteria could be a reflection of the distribution of assimilable organic matter in the Bay indicating the possibility that major sedimentation and mineralization occur in this area with little organic matter being transported to other sectors of the Bay. The validity of this conclusion is being investigated.

D. *Sewage treatment plants* (Table 4). Fecal coliform bacteria were present in high numbers in the effluent from both the Kaneohe municipal plant and the KMCAS plant. On the days when the analysis were made the treatment process of the latter plant has not significantly removed fecal microorganisms. Surprising was a rather high count in the municipal effluent. Two tests

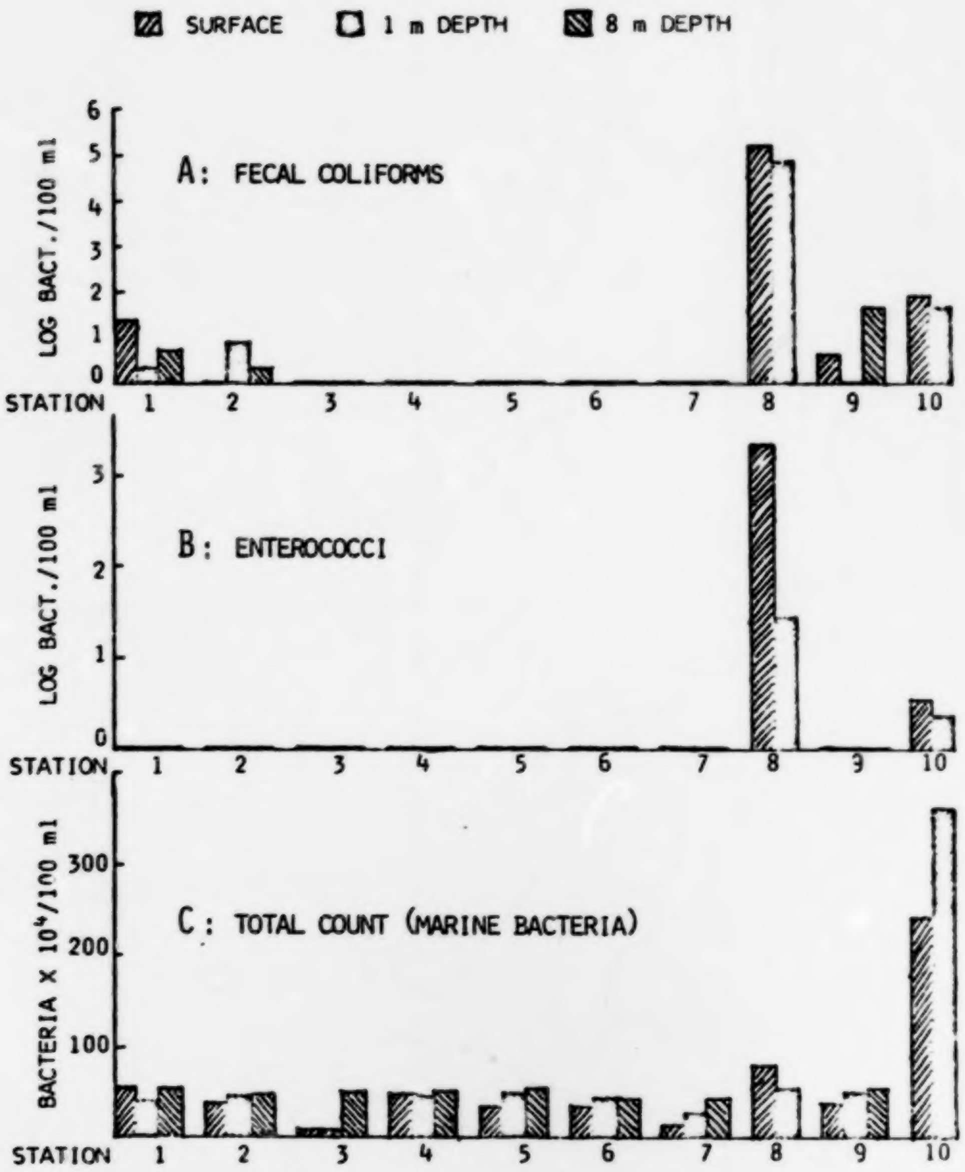


FIGURE 2. BACTERIOLOGICAL ANALYSIS:KANEOHE BAY JULY-NOVEMBER 1968.

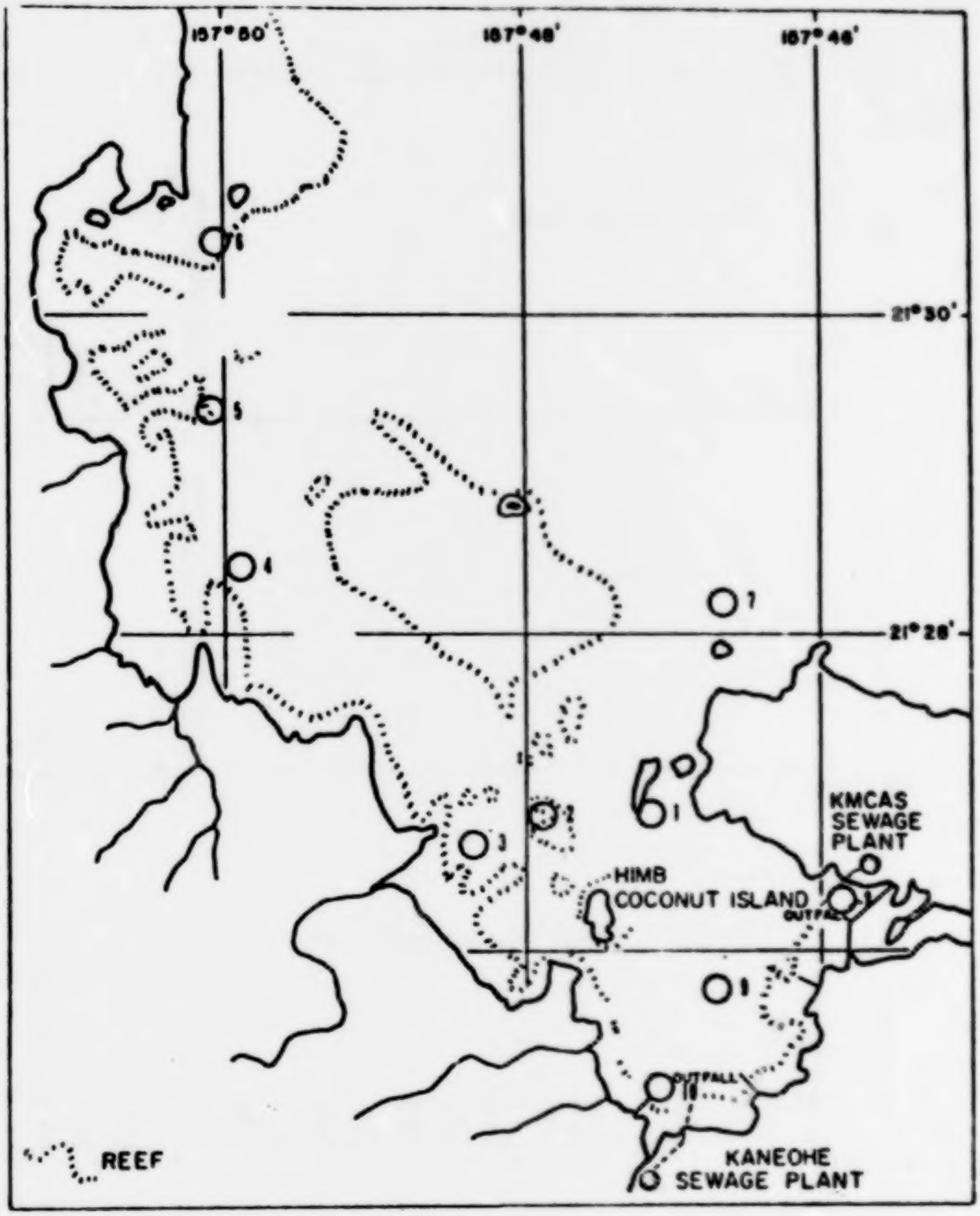


FIGURE 1. SITE LOCATION MAP.

Table 1: Fecal coliforms per 100 ml of water

Date	Depth	Station									
		1	2	3	4	5	6	7	8	9	10
July 31	0	-	-	2	0	0	0	0	-	-	-
	1	-	-	0	0	0	0	0	-	-	-
	8	-	-	0	0	0	0	0	-	-	-
Aug. 7	0	0	0	-	-	-	-	-	>7,600	3	9
	1	0	0	-	-	-	-	-	0	0	11
	8	0	0	-	-	-	-	-	-	93	-
Aug. 14	0	-	-	0	0	0	2	0	-	-	-
	1	-	-	0	0	0	0	0	-	-	-
	8	-	-	0	0	2	0	0	-	-	-
Aug. 21	0	200	3	-	-	-	-	-	>20,000	6	6
	1	0	2	-	-	-	-	-	248	0	0
	8	0	0	-	-	-	-	-	-	2	-
Aug. 28	0	0	0	-	-	-	-	-	320,000	0	12
	1	0	14	-	-	-	-	-	370,000	0	9
	8	0	0	-	-	-	-	-	-	1	-
Sept. 11	0	2	0	-	-	-	-	-	291,000	0	85
	1	2	0	-	-	-	-	-	3,705	0	22
	8	0	0	-	-	-	-	-	-	2	-
Sept. 26	0	2	0	-	-	-	-	-	543,000	2	420
	1	2	0	-	-	-	-	-	153,000	0	34
	8	2	0	-	-	-	-	-	-	2	-
Oct. 10	0	2	0	-	-	-	-	-	391,000	-	-
	1	4	36	-	-	-	-	-	3,700	-	-
	8	21	16	-	-	-	-	-	-	-	-
Oct. 24	0	0	2	-	-	-	-	-	250	14	38
	1	0	2	-	-	-	-	-	1,260	6	12
	8	2	0	-	-	-	-	-	-	3	-
Nov. 7	0	5	0	-	-	-	-	-	17,400	5	56
	1	0	0	-	-	-	-	-	960	0	9
	8	19	0	-	-	-	-	-	-	2	-
Nov. 21	0	0	0	-	-	-	-	-	86,400	2	42
	1	4	0	-	-	-	-	-	9,700	0	15
	8	0	0	-	-	-	-	-	-	2	-

Table 2: Enterococci per 100 ml of water

Date	Depth (m)	Station									
		1	2	3	4	5	6	7	8	9	10
July 31	0	-	-	0	0	0	0	0	-	-	-
	1	-	-	0	0	0	0	0	-	-	-
	8	-	-	0	0	0	0	0	-	-	-
Aug. 7	0	0	0	-	-	-	-	-	75	0	0
	1	0	0	-	-	-	-	-	66	0	1
	8	0	0	-	-	-	-	-	-	0	-
Aug. 14	0	-	-	0	0	0	0	0	-	-	-
	1	-	-	0	0	0	0	0	-	-	-
	8	-	-	0	0	0	0	0	-	-	-
Aug. 21	0	0	0	-	-	-	-	-	2,335	0	0
	1	0	0	-	-	-	-	-	0	0	0
	8	0	0	-	-	-	-	-	-	0	-
Aug. 28	0	0	0	-	-	-	-	-	2,600	0	1
	1	0	0	-	-	-	-	-	3,800	0	1
	8	0	0	-	-	-	-	-	-	1	-
Sept. 11	0	0	2	-	-	-	-	-	510	0	8
	1	0	2	-	-	-	-	-	4	0	6
	8	0	0	-	-	-	-	-	-	4	-
Sept 26	0	2	0	-	-	-	-	-	96	0	0
	1	0	0	-	-	-	-	-	0	2	0
	8	0	0	-	-	-	-	-	-	0	-
Oct. 10	0	0	0	-	-	-	-	-	6,950	-	-
	1	0	6	-	-	-	-	-	0	-	-
	8	2	4	-	-	-	-	-	-	-	-
Oct. 24	0	0	0	-	-	-	-	-	290	0	6
	1	4	0	-	-	-	-	-	0	0	2
	8	0	0	-	-	-	-	-	-	0	-
Nov. 7	0	0	0	-	-	-	-	-	1,034	0	4
	1	0	0	-	-	-	-	-	0	0	0
	8	0	0	-	-	-	-	-	-	0	-
Nov. 21	0	0	0	-	-	-	-	-	4,240	0	10
	1	0	0	-	-	-	-	-	170	0	8
	8	0	0	-	-	-	-	-	-	0	-

Table 3: Total bacterial count per 100 ml of water

All values x 10^4

Date	Depth (m)	Station									
		1	2	3	4	5	6	7	8	9	10
July 31	0	-	-	16	24	7	5	1	-	-	-
	1	-	-	7	4	23	4	2	-	-	-
	8	-	-	17	23	21	3	4	-	-	-
Aug. 7	0	51	3	-	-	-	-	-	89	7	406
	1	2	17	-	-	-	-	-	34	4	530
	8	26	14	-	-	-	-	-	-	6	-
Aug. 14	0	-	-	6	74	60	70	29	-	-	-
	1	-	-	7	90	80	90	56	-	-	-
	8	-	-	94	90	90	90	90	-	-	-
Aug. 21	0	40	31	-	-	-	-	-	227	10	190
	1	11	48	-	-	-	-	-	26	11	244
	8	29	158	-	-	-	-	-	-	5	-
Aug. 28	0	17	2	-	-	-	-	-	43	7	194
	1	18	8	-	-	-	-	-	17	22	314
	8	87	20	-	-	-	-	-	-	21	-
Sept. 11	0	25	63	-	-	-	-	-	85	30	775
	1	9	11	-	-	-	-	-	67	885	1,170
	8	35	28	-	-	-	-	-	-	112	-
Sept. 26	0	60	6	-	-	-	-	-	10	29	32
	1	73	1	-	-	-	-	-	12	25	22
	8	33	1	-	-	-	-	-	-	22	-
Oct. 10	0	44	51	-	-	-	-	-	88	-	-
	1	9	63	-	-	-	-	-	50	-	-
	8	14	10	-	-	-	-	-	-	-	-
Oct. 24	0	190	140	-	-	-	-	-	190	151	180
	1	200	170	-	-	-	-	-	180	181	250
	8	180	171	-	-	-	-	-	-	250	-
Nov. 7	0	50	17	-	-	-	-	-	115	34	15
	1	9	9	-	-	-	-	-	35	25	14
	8	35	16	-	-	-	-	-	-	9	-
Nov. 21	0	73	44	-	-	-	-	-	104	33	117
	1	34	105	-	-	-	-	-	25	104	347
	8	64	30	-	-	-	-	-	-	64	-

performed in 1967 revealed no coliforms or other bacteria in the effluent from this source presumably due to excessive chlorination.

Table 4: Fecal coliforms in sewage received and discarded by Kaneohe Bay sewage plants

		Counts per 100 ml			
Date	Plant	Raw Sewage	After primary filtration	After biofilter	Effluent
July 9	Kaneohe Municipal	4.9×10^7	6.1×10^7	2.9×10^7	2.0×10^4
Sept. 5	KMCAS	4.0×10^7	-	-	1.7×10^7

E. Nitrification. Enrichment cultures for ammonium and nitrite-oxidizing chemoautotrophic bacteria have been grown following monitoring at all ten stations at all 3 depths, except for stations 8 and 10 which have only 2 sampling depths. Nitrification has been found significant at stations 8 and 10 (sewage outfalls) but stray-positives were also obtained in water from a few other stations. It is, however, too early to draw any conclusions as to the quantitative significance of the nitrification process in the Bay. Recorded data and data expected during the second half-year of the pollution study will be evaluated together with data from chemical analysis and from the mineralization experiments.

F. Anaerobic bacteria. Studies of the distribution of anaerobic bacteria in the waters of Kaneohe Bay and the relation of the aerobic : anaerobic counts to the amount of dissolved oxygen have been initiated. No data are as yet ready for reporting, but results which have been obtained to date have encouraged intensification of this research. Incidentally, this study has led to the discovery of a new and very simple method of quantitating sulfate-reducing bacteria and the isolation of such bacteria in pure culture from plates containing a special agar medium incubated under hydrogen gas.

G. Mineralization. We are currently testing different methods which could be used for routine determination of mineralization rates. No data are as yet ready for reporting.

H. Productivity. Lack of personnel has made it impossible to initiate any productivity determinations in the Bay. However, two graduate students from the Department of Microbiology are currently planning a study of the activity of photosynthetic bacteria in Kaneohe Bay and might, in connection with this work, make some determinations of total productivity. If this is done in time, the results will be included in the final report.

ORGANICS

by

Keith E. Chave

Harold Schiesser

Dissolved and particulate organic materials in Kaneohe Bay are derived from the organisms in the Bay, from rivers entering the Bay, from sewage outfalls, and from the open ocean outside the Bay. Each source provides a different quality and quantity of material to the Bay.

Organic matter in the water may be beneficial or detrimental to the growth of normal Bay organisms, depending upon its concentration, composition and physical state.

Organic pollution can require a nearly endless series of studies of effects of specific compounds on specific organisms, or effects of varying concentrations and combinations of compounds, of natural populations in different locations in a polluted region, etc. On the basis of the hypothesis that dissolved organic can act as *pollutants*, yet the source materials in the particulate state can serve as *nutrients*, mechanisms and rates of transformation of dissolved organics into the particulate state will be the focus of this sub-project. We are also comparing these processes in areas of low and high organics, unpolluted and polluted areas, respectively.

Our goal is to understand how these pollutants become nutrients in nature, and perhaps to suggest how this process could be artificially speeded up for the benefit of the estuary.

Progress

The work to date has involved the development of suitable sensitive analytical techniques, and experiments on the transformation of natural dissolved organics into the particulate state. We are studying changes in organic carbon, nitrogen, and phosphorus.

A. Analysis. The development of analytical techniques suitable to the specific problem at hand is a necessary, if unspectacular, part of any research problem in ocean chemistry. In this initial phase, new, or modifications of old methods, have been developed to the point where we now have suitably accurate and precise methods for the determination of dissolved carbon and phosphorus, and particulate carbon, phosphorus, and nitrogen at the concentrations found in our experiments.

B. Transformation of dissolved to particulate organics. The transformation of organics from the dissolved to the particulate state appears to be most rapid at an interface -- air-water or mineral-water. Two interfaces have been studied to date -- the air-water interface of air bubbles, and the mineral-water interface of $CaCO_3$ precipitating from supersaturated seawater. Both interfaces appear to be very effective in transforming dissolved organics into the particulate state.

C. Bubbles. Kaneohe Bay water containing approximately 2.0 mg/l dissolved organic carbon and 0.3 mg/l particulate organic carbon was used in most experiments.

Water was prepared for bubbling by pressure filtration through a 1.2μ silver filter. Bubbling was carried out in a plastic cylinder with a 5 to 8-liter water sample, using filtered air passing through a sintered glass orifice. After bubbling the water was refiltered and the filter was analysed for particulate organics. Table 1 shows the amount of particulate organics formed as a function of time of bubbling.

TABLE 1. FORMATION OF PARTICULATE ORGANICS

Time/hrs	Particulate		C/N	% Dissolved C
	C(mg/l)	N(mg/l)		
1	.099	.008	12.4	5%
3	.073	.010	7.3	3.6%
5	.088	.012	7.5	4.4%

The data suggest that particle formation is rapid, and that extended bubbling does not produce more particles. Approximately 5% of the dissolved organics can be transformed into particles in an hour. The C/N ratio of about 10 suggests that the particles contain enough proteinaceous material to provide nutrition to animals feeding on them.

Repeated bubbling of one water sample continues to produce particulate matter. Filtered water was bubbled for 48 hours, filtered, and bubbled for another 16 hours. Filtered material obtained after the first and second bubbling were analysed and the results are shown in Table 2.

TABLE 2. EFFECT OF RE-BUBBLING

Water Sample Site	Bubbling	C(mg/l)	N(mg/l)	C/N
Open Bay Water	1st	.026	.0022	11.8
	2nd	.028	.0032	8.7
Water Near Sewer Outfall	1st	.211	.0038	55.5
	2nd	.038	.0025	15.2

The data suggest that particles can be produced from waters containing normal dissolved organics. Upon bubbling, particles are physically or microbiologically destroyed, but if particles are removed, new ones are formed. Polluted water apparently contains compounds which behave differently from those in normal Bay waters. Prolonged bubbling produces lower values than for those shown for normal Bay waters in Table 1. These bubbling experiments are being continued in the second six-month period.

Carbonate Precipitation

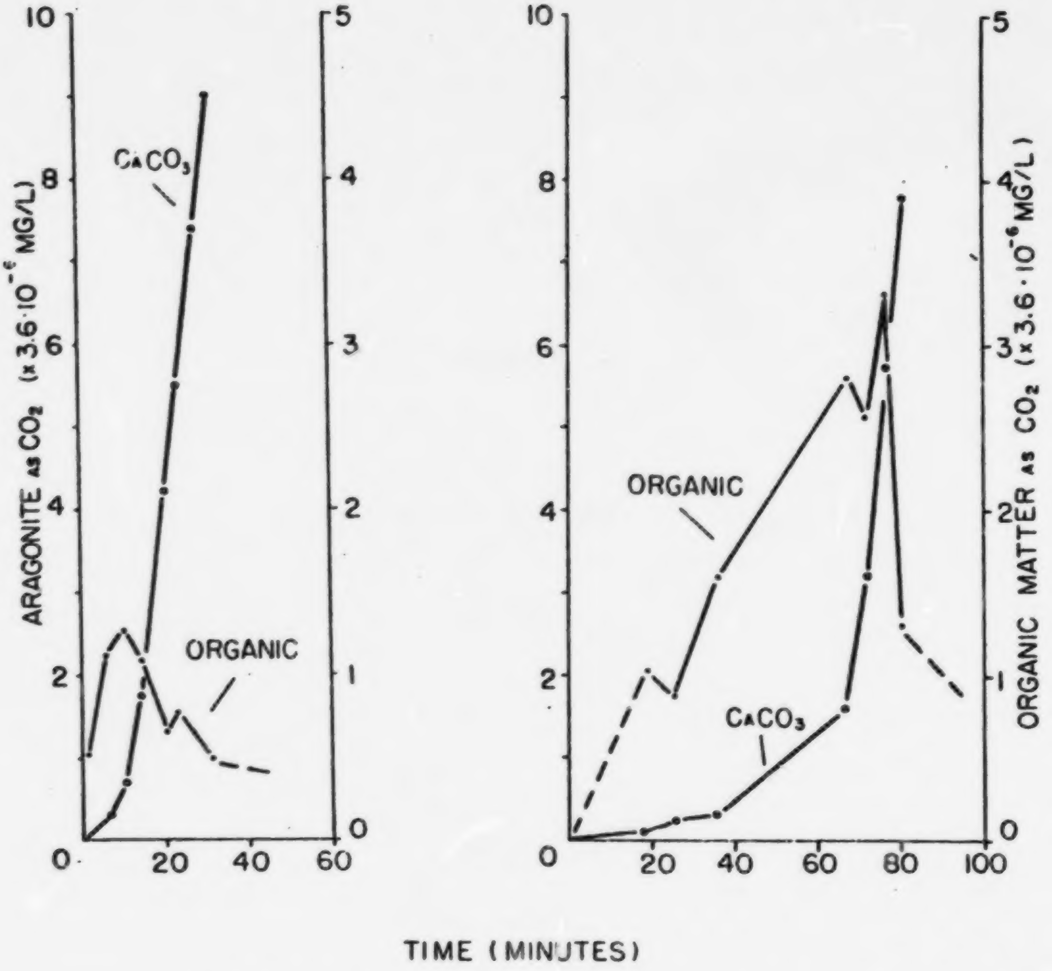
Kaneohe Bay waters are supersaturated with $CaCO_3$ at all times, and hence, it may precipitate out at any time. In addition, the Bay waters contain quantities of suspended $CaCO_3$, derived from reef organisms. The surface of $CaCO_3$ particles appear to concentrate organics from solution, and transform them into a particulate state.

In two experiments, filtered Bay water was made highly supersaturated with $CaCO_3$ by addition of 0.1 m Na_2CO_3. As carbonate precipitation occurred, particulate organic carbon was determined. The results of this experiment are shown in Figure 1. At various times after addition of Na_2CO_3, which caused the pH to increase to 9.5, samples of the water were filtered and analysed for particulate $CaCO_3$ and organic carbon. As indicated by the figure, particulate organic carbon is formed just before and during the rapid precipitation of $CaCO_3$.

Summary

Organic matter in Kaneohe Bay may act as pollutants when in the dissolved state and may serve as nutrients in the particulate state.

Much of the early effort in the study was directed toward the development of analytical techniques which are now satisfactory. The transformation of dissolved to particulate organics at interfaces, a process which occurs rapidly at bubble and mineral surfaces, will be the focus of this study for the next six months.



COMPOSITION OF SEAWATER PRECIPITATE

PLANKTON

by

Robert I. Clutter

Except for the shallows and coral reefs, the plants and animals in Kaneohe Bay either live in the open water or largely depend on the open water biological community for energy. Changes in community structure, associated with changes in the environment, seem likely to occur first in the plankton, because the plants and herbivores are small and have potentially high rates of population increase (or decline). Since these small organisms tend to be close to the base of the energy pyramid, changes in their species-abundance relationships might alter the whole trophic structure of the Bay.

The purpose of this plankton program is to assess the distribution and abundance of the plankton in Kaneohe Bay, and to establish trophic relationships and energy pathways. In the final analysis, we will attempt to determine the relationships between the plankton and certain features of the environment. For the present report, we have attempted to supply some answers to the following two questions only:

(1) Does the Bay have an homogeneous plankton community structure?
(2) Which sub-regions of the Bay should we compare to define the possible effects of introducing plant nutrients?

Sampling

For the survey work, phytoplankton (including plant pigments) and zooplankton samples have been taken at the same sampling stations occupied for chemical and microbiological studies (Figure 1). The phytoplankton were sampled from the surface with closing bottles. The zooplankton were sampled from near the bottom up to the surface with a paired net devised for this study. One half of this device samples animals larger than 0.333 mm and the other half samples organisms between 0.065 mm and 0.333 mm.

Results

Phytoplankton. The samples includes at least thirty-three species of diatoms, three species of dinoflagellates and one species each of ciliate and blue-green alga. The distributions of numbers of plant cells and pigment densities per unit volume of water have been determined for six sampling periods at each of the 10 stations. This summary deals only with the average distributions of total cells and chlorophyll-a.

As shown in Figure 2, phytoplankton and chlorophyll-a abundance decreases from the southern to the northern end of the Bay. The highest values occur at station 10, in the extreme corner of the southern sector near the sewer outfall of the municipality of Kaneohe. The lowest values occur in the neritic zone outside the Bay.

Further analysis will include more rigorous evaluation of cell counts per species and estimates of species diversity as well as pigment diversity (other pigments are not included in the present summary).

Zooplankton. Three sets of ten samples each have been analysed for species-abundance data for the larger zooplankton. This analysis includes complete counts of 47,500 individuals belonging to thirty-five taxa (about twice this number of species). Zooplankton samples were not taken at stations 8 and 10, near the two sewer outfalls, because they would be meaningless as estimates of secondary productivity.

As shown in Figure 2, the abundance of larger (>0.3 mm) zooplankton follows approximately the same decline sequence from south to north to neritic as the phytoplankton.

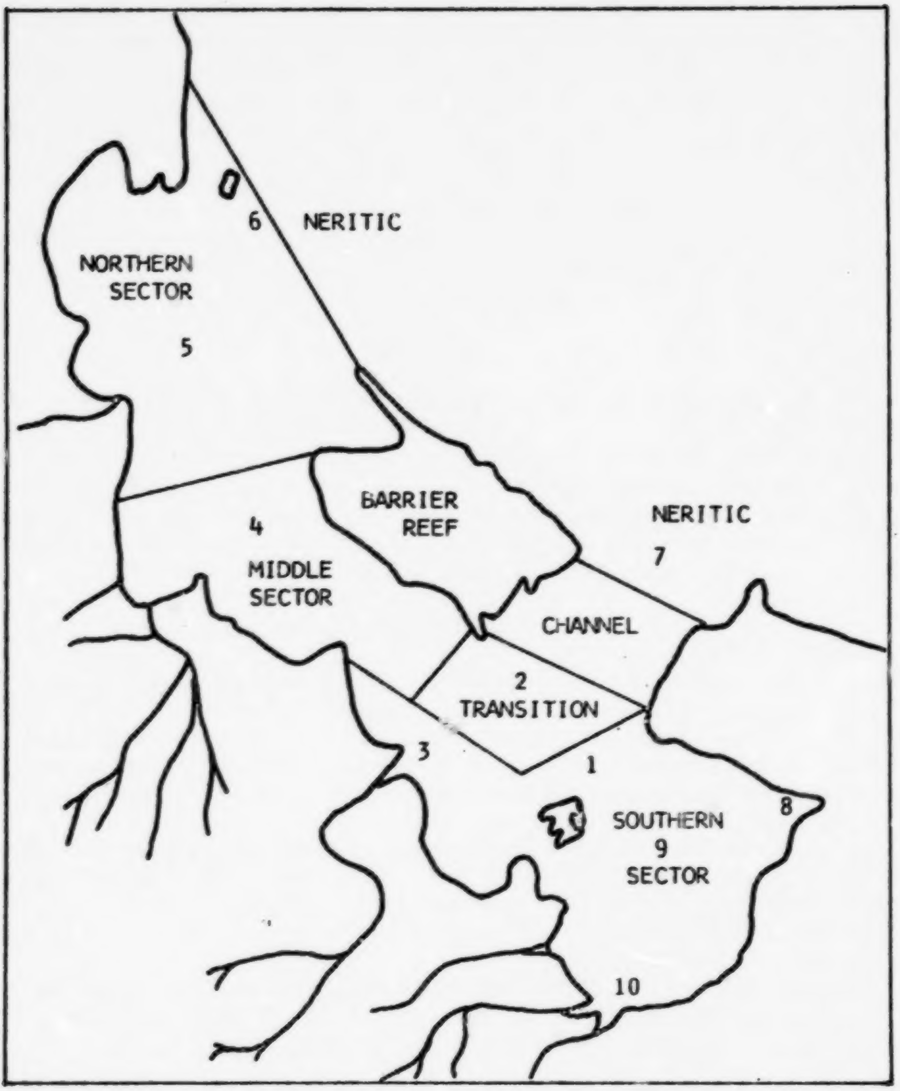


FIGURE 1. CHART OF KANEOHE BAY SHOWING STATION POSITIONS (1-10) AND TENTATIVE BIOGEOGRAPHIC DIVISIONS.

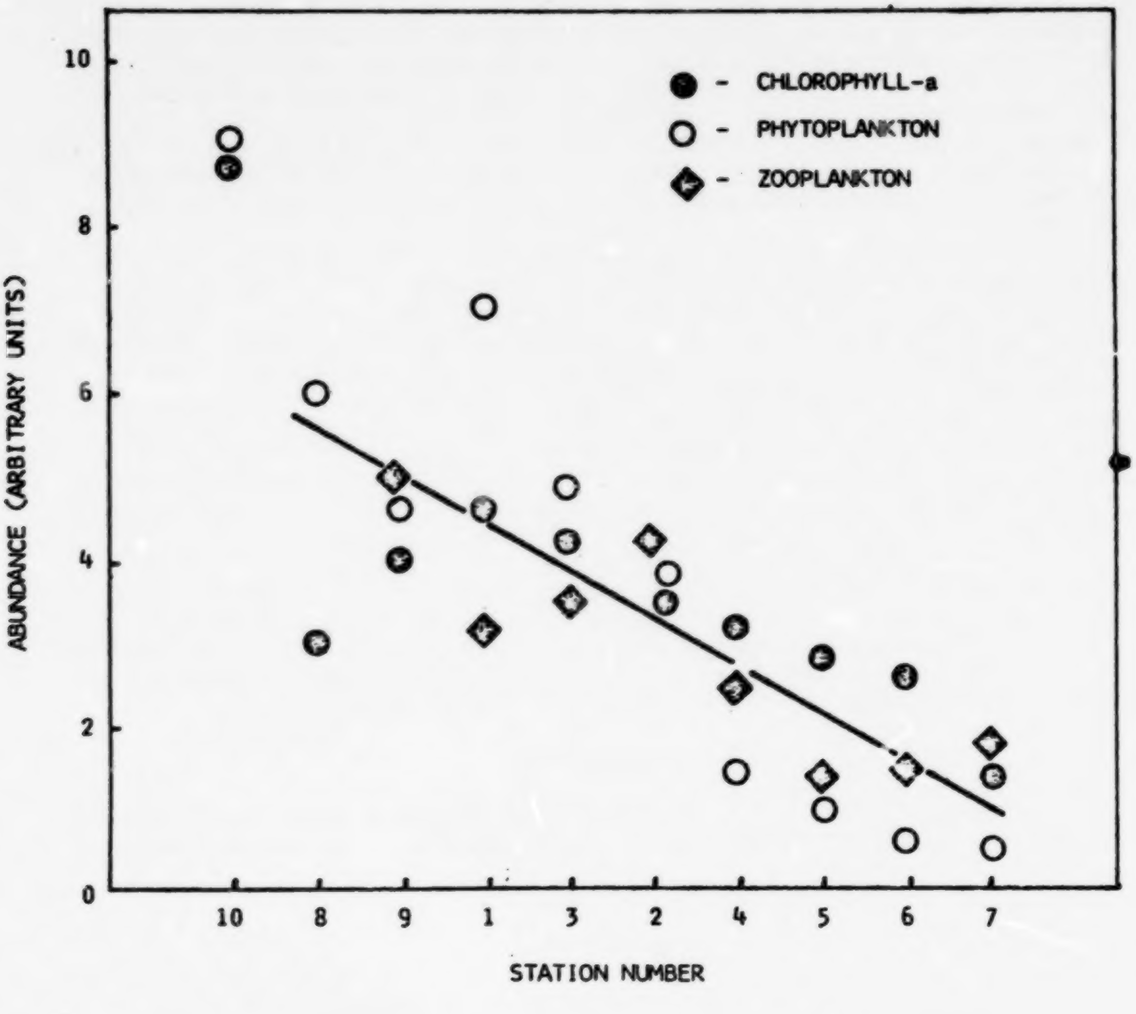


FIGURE 2. RELATIVE ABUNDANCE OF CHLOROPHYLL-a, PHYTOPLANKTON AND LARGER ZOOPLANKTON AT KANEOHE BAY SAMPLING STATIONS (CF. FIGURE 1).

Further analysis will include estimating the species diversity of these larger zooplankton at the several sampling stations, and estimating the species-abundance for the smaller zooplankton (>0.06 mm, <0.3 mm) at selected stations.

Conclusions

From this study and corollory studies (Peterson, M. S. thesis) on the distribution of Kaneohe Bay plankton we conclude that Kaneohe Bay does not have either uniform standing stocks nor an homogeneous community structure. This is indicated by "indexes of diversity" which take into account not only the numbers of taxa but the distributions of numbers within taxa. Diversity indexes are particularly useful for comparing samples from linked communities such as occur in Kaneohe Bay. Community composition is similar throughout the Bay, but relative abundances of the common components vary from sector to sector.

The results of this work suggest that the Bay may be divided into the biogeographic sectors shown in Figure 1. The "southern" sector, a region of high stream runoff and input from two sewer outfalls, has the highest standing stocks of plankton and the lowest biological diversity. The "transition" sector has intermediate standing stocks and the highest diversity in the Bay. This high diversity occurs because it is a kind of "ecotone", which includes neritic species that are brought in through the channel. The "middle" and "northern" sectors are more diverse than the southern sector and have lower standing stocks. The "channel" sector is a more shallow region where the community composition changes regularly with tidal exchange. The "neritic" region contains a very different community.

In the second half-year of the study, the southern and the middle sectors of the Bay will be compared in detail to define the possible effects of introducing plant nutrients. These two sectors are most alike of all, except for the differences in standing stocks, which presumably are related to differences in nutrient input and retention. Studies of trophic structure and energy pathways will be done in these two sectors only.

Reference

Peterson, William T., M. S. thesis, *The Distribution of the Zooplankton of Kaneohe Bay, Oahu,* University of Hawaii, Honolulu. In preparation.

SEDIMENTATION

by

Ralph M. Moberly, Jr.

Pow Foong Fan

Progress in the sediment studies in Kaneohe Bay has been slow due to three main causes: (1) there have been only two moderate and no severe rainstorms this season over the Kaneohe watershed, hence, we still have no measurement of suspended sediment during peak discharge of streams, (2) the three x-ray diffraction machines on campus have been out of commission for most of the past several months, causing a lag in the analysis of sediment for crystalline (mineral) material, and (3) delivery and installation of a high-temperature furnace was not completed until more than 5 months after the order was placed, thus, our analysis of sediment for amorphous (mineraloid) material has not commenced.

Of the x-ray work that we have been able to schedule, the carbonate identifications are well underway. The carbonate content of the sediment on the fringing reef of the south half of the bay (where stream runoff has increased in the past few years) is about 25% calcite and 77% aragonite. The carbonate content of the sediment on the so-called barrier reef is about 61% calcite and 39% aragonite. Differences are due to varying contributions by different calcareous-shelled organisms. Because of the deep water between the two areas, it is not likely the sands of these two areas mix. Detrital (eroded basalt) sand reaches one area but not the other. Because carbonate sand so dominates the total sand of Kaneohe Bay, we expect that maps of carbonate mineralogy will be a useful supplement to such maps as percentage of detrital sediment, or grain size, in determining sand transport in the bay.

A network of lines of fathometer runs in the southwestern corner of the bay has been completed and will allow a more precise determination of the bathymetry than Coast and Geodetic Survey chart 4134. From the angles of the slopes and the sediment parameters, some estimate can be made of the probability that shallow muds deposited off the stream mouths will slump into deeper water, and if so, along what direction.

ALTERNATIVES

by

Brian Gray

L. Stephen Lau

Inasmuch as the alternatives sub-project will involve utilization and interpretation of data collected by other sub-projects, the progress at this time is limited to collection and review of background information, establishing future population projections, and ascertaining that the data being gathered by other sub-projects will be sufficient for estimating the costs of alternative methods.

Population Projection[1]

Source of reference: City and County of Honolulu, April 1968.

Area	April 1960 U. S. Census	July 1967 (Estimate)	Projections		
			1970	1980	1985
Kualoa-Kahaluu-Heeia	4,990	13,586	15,000	22,500	27,000
Kaneohe	16,526	28,179	30,500	44,000	49,000
Mokapu MCAS	6,397	6,947	6,000	6,000	6,000
Total around Kaneohe Bay	27,913	48,712	51,500	62,500	82,000

Sewage Effluent

Information is being gathered on the effluents from sewage treatment plants discharging into the Bay as well as other sewage treatment plants in Honolulu in order to determine the necessary degree of tertiary treatment to meet the Water Quality Standards.

Preliminary investigations have indicated the following most probable alternatives for Kaneohe sewage treatment plant:

(1) Tertiary treatment
(2) Ocean outfall across the bay
(3) Gravity sewer and force main to Mokapu Point and thence to an ocean outfall
(4) Gravity sewer and force main to Aikahi sewage treatment plant to an outfall into Kailua Bay.

The effluent from the sewage treatment plant at the Marine Corps Air Station, Mokapu could receive tertiary treatment, or could discharge into one of the outfalls proposed for Kaneohe sewage treatment plant.

Stream Discharge

The sedimentation sub-project will prepare estimates of the silt load discharging into the Bay. The sanitary quality group will sample the water quality at eleven stream stations including upstream controls and will test for nutrients as well as bacteriological quality for MPN, coliform, fecal coliform, and fecal streptococcus.

The U. S. Geological Survey began a program of sampling sediments in Hawaiian streams about a year ago and has planned to sample some of the streams contributory to Kaneohe Bay during the rainy season. The alternative sub-project has been in close contact with the U. S. Geological Survey and has made arrangement for interchange of information and coordination.

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[1] Projections were based on present zoning and available land for development.

A map of the catchment around Kaneohe Bay herein appended has been prepared. Historical data of streamflow discharge has been obtained and is being processed.

1968 Spring Survey

A sanitary quality survey was conducted between February and April 1968 of the surface water quality in the southeastern portion of Kaneohe Bay and the quality of the stream water discharging into that part of the Bay. The findings are available for this contract study and are presented in a M. S. thesis entitled,"Some Aspects of Pollution in Kaneohe Bay, Oahu and its Effects on Selected Microorganisms," by Edison Quon.

Sub-project Approval

The Office of Estuarine Studies, FWPCA has given approval for the University to let a sub-project with Mr. Brian Gray under Dr. Stephen Lau's supervision. Mr. Gray is a practicing civil engineer with R. M. Towill Corporation, Honolulu, Hawaii and is presently on leave to pursue graduate studies in sanitary engineering at the University of Hawaii.

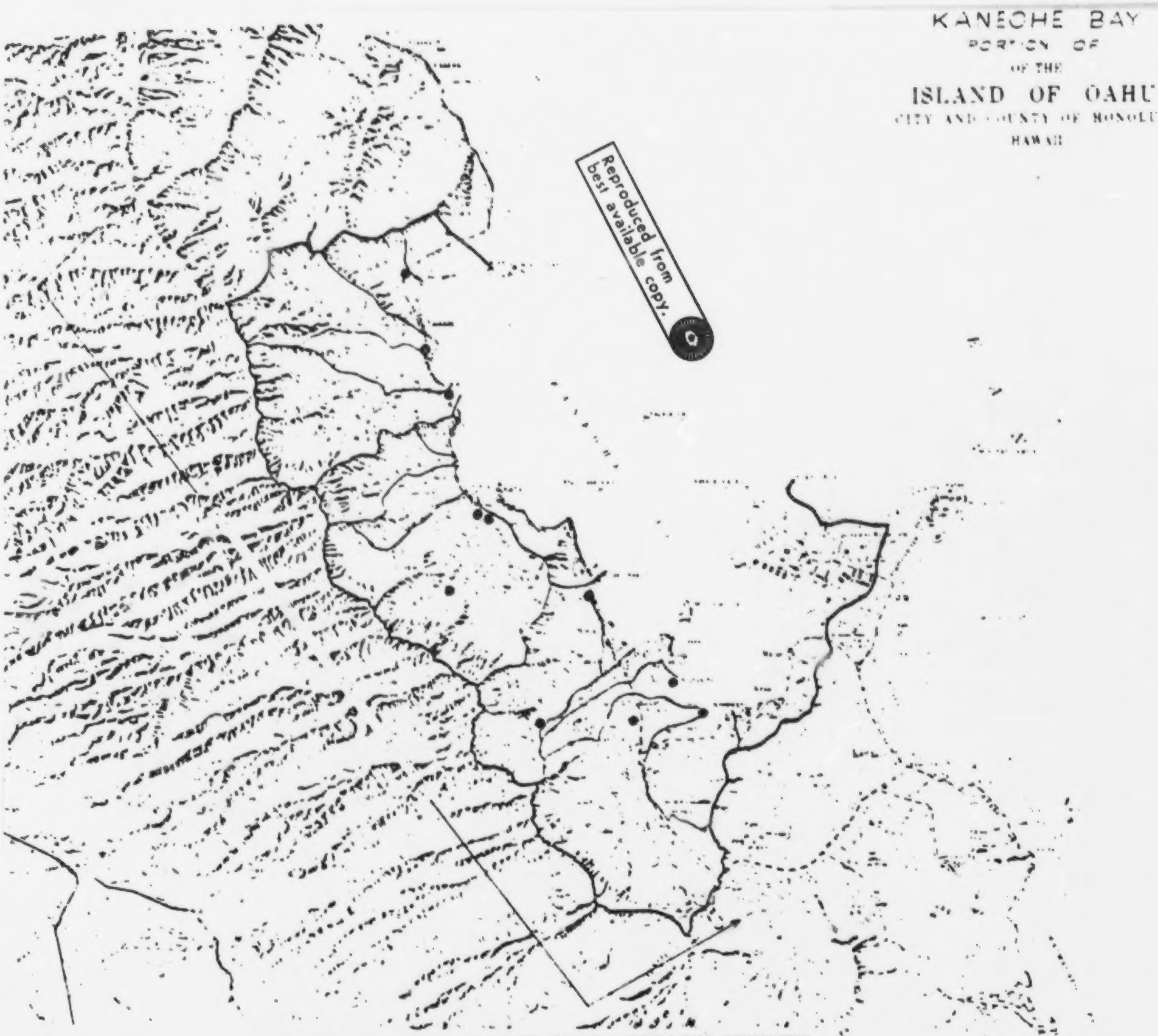
Dr. Lau is assisted by Drs. N. C. Burbank, R. H. F. Young, and H. Yamauchi in Mr. Gray's graduate committee.

Sub-project Outline

The outline which follows will serve as guidelines for the conduct of the sub-project preparation of the final report.

Proposed Outline of the Study

Purpose and Scope
Review of Previous Studies
Disposal of Sewage Effluent
    Characterization of effluents
        (a) Raw sewage
        (b) Primary effluent
        (c) Secondary effluent
        (d) Tertiary effluent
            Characterize the quantity and quality of the existing effluents discharging into Kaneohe Bay as related to Hawaii W.Q.S., and project future discharge.
    Characterization of Bay water
        Relate existing data gathered by other study groups to Hawaii W.Q.S.
    Characterization of environmental factors
        (a) Hydrographic data: currents, tides, soundings
        (b) Meteorological data: wind, temperature, rainfall
    Prediction of resulting quality by zone
        (a) Settling
        (b) Dilution and mixing
        (c) Dispersion
        (d) Chemical reactions and precipitation



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ESTUARINE POLLUTION PROJECT STREAM SAMPLING STATIONS

(e) Adsorption
(f) Ion exchange
(g) Growth and death of sewage bacterial indicators

Prediction will relate to test samples taken at the surface and depths of 1 meter and 8 meters. For the purpose of this study a zone of mixing of 200 ft. radius at sewer outfalls will be assumed unless conditions warrant otherwise.

Alternative methods of disposal

(a) Types of treatment including secondary and tertiary
(b) Ocean outfall
(c) Exportation by gravity sewers and force mains
(d) Deep well injection
(e) Combinations of above
(f) Consideration by area and season if applicable

Costs

Costs of capital improvements and operation for alternative methods of disposal listed above as related to:

(a) Hawaii Water Quality Standards
(b) Water quality beyond the minimum standards

Stream Discharge

Characterization of stream discharge

(a) Hydrology
(b) Dry-weather flow characteristics
(c) Flood-flow characteristics
(d) Future patterns

Characterizing quality of discharge as related to Hawaii Water Quality Standards

Characterization of Bay water

Relate existing data gathered by other study groups to Hawaii W.Q.S.

Characterization of environmental factors

(a) Hydrographic data: currents, tides, soundings
(b) Meteorological data: wind, temperature, rainfall

Prediction of resulting quality by zones

Physical, chemical and biological effects related to:

(a) Settling
(b) Dilution and mixing
(c) Dispersion
(d) Chemical reactions and precipitation
(e) Adsorption
(f) Ion exchange
(g) Growth and death of organic bacterial indicators

According to the Hawaii W.Q.S., erosion occurring under natural conditions does not constitute a violation, and, further, when development is carried out in accordance with acceptable conservation practices future development will not constitute a violation.

Alternative methods of control

(a) Watershed Management

(i) Soil Conservation Methods
(ii) City and County Control
(iii) Construction methods
(iv) Future development

- (b) Stream Management
  - (i) Stream revetment
  - (ii) Small detention structures and sedimentation basins
  - (iii) Dredging stream mouths
  - (iv) Centrifuging stream discharge
  - (v) Exportation
  - (vi) Recharge

Costs

Costs of capital improvements and operation for alternative methods of control listed above as related to:

- (a) Hawaii Water Quality Standards
- (b) Water Quality beyond the Standards

Conclusions and Recommendations

ECONOMICS

by

Hiroshi Yamauchi

Conduct of the Study

The introductory descriptive survey is limited only to beneficial uses which fall within the category of recreation and commercial fisheries. Other beneficial uses of the Bay such as for scientific research, a depository for municipal wastes and stream discharges, etc., are also recognized to be important. However, these activities are presumed to be adequately covered in their separate analyses elsewhere in the overall project. Recreational activities include all forms of boating, water skiing, fishing, clamming, and deep-sea sportfishing originating from public and private small boat harbors and piers within the Bay. Commercial fisheries include nehu fishery as a bait for commercial aku fishermen, fishponds, and other private commercial fishermen operating out of the Bay.

The major purpose of this study focuses on the issue of the economic feasibility of implementing the standards program, where such economic feasibility is viewed in terms of state and local fiscal capacities. A thorough understanding of this issue in terms of fiscal capacities can be useful in isolating underlying economic factors which operate in placing an upper limit on the total economic and non-economic values which are to be safeguarded by the standards program. Deriving a sound judgment of the limiting state and local fiscal capacities precludes not only the necessity of empirically measuring economic values of market activities for which collecting the relevant data may be difficult, but also the even more frustrating task of conceptually rationalizing under, heroic assumptions, a method for empirically imputing monetary values on extra-market activities such as recreation, aesthetics, and health.

A general statement is being formulated from a careful review of the standards program relative to fiscal budgeting for water quality conservation and the imperfections and uncertainties of the program. The observations at this point are as follows. The establishment of present and prospective best use for each coastal area and a set of physical criteria for water quality to conform with the designated uses potentially serve as an engineering basis for estimating fiscal budget requirements. However, to the extent that the standards are imperfect and uncertainties exist, the immediate usefulness of the standards to serve as a positive device for water quality conservation remains small. In this situation, the opposite relationship may be expected; the budgeting for overall economic growth and development of the state is likely to have the controlling influence on the effectiveness of the standards to serve as a reliable basis for water quality conservation budgeting. Nevertheless, despite the present imperfections and uncertainties, the initial setting of the standards has had the impact of setting into motion further research and the periodic review and revision of the standards to take into account the changing state of the arts make the standards a potentially dynamic device for continually removing imperfections and uncertainties. In this light, the effectiveness of the standards as a basis for water quality conservation budgeting depends in large part upon the viability of research and its contribution towards improving the standards themselves.

In order to carry out a meaningful analysis of the economic feasibility of implementing the standards, a basic understanding of the state and local fiscal and long-term debt structure is necessary. An excellent reference for this purpose has been *Government in Hawaii*, a handbook of financial statistics published annually by the Tax Foundation of Hawaii. In general the tax structure of Hawaii is highly centralized at the State's Department of Taxation which levies, administers, and collects almost all taxes with certain exceptions. These exceptions have been summarized and data on sources of revenues for capital improvements and operating budgets are being organized. In addition per capita tax burden relative to personal income is being examined as a possible index for fiscal capacity.

Since bonding is likely to be an important financing alternative, the state and local long-term debt structure must also be clarified. Hawaii's total long-term state and local debt structure has been represented in terms of "funded debt" and "public bonded debt." "Funded debt" which has been charged against the state's constitutional debt limit up until now has included all state and county general obligation and revenue bonds plus other state bonds that have been authorized but are unissued. The changes in the recent state constitutional amendments have been noted and are being carefully studied along with data for the past ten years of record (fiscal 1957-1967).

"Public bonded debt," on the other hand, includes only outstanding bonds, both general obligation and revenue issues. Not all revenue bonds, however, are included. Of particular interest are the exclusions of certain federally backed revenue bonds (*i.e.*, Hawaii Housing Authority revenue issues) as well as Improvement District Bonds of the City and County of Honolulu which are repaid from special assessments on real property owners. But, at the same time, other revenue issues which are repaid by special earmarked receipts such as airport earnings, harbor funds, fuel tax collection, highway revenues, and water fees are included. The effect of these differences on fiscal capacity and their implications for water quality conservation budgeting is being ascertained.

Finally, five interrelated problem areas are being studied. These have to do with:

(1) the availability of federal assistance program,
(2) the distribution of general excise taxes in the form of state grants to counties,
(3) the use of general revenue surpluses for cash expenditures in capital improvement projects,
(4) the general lack of earmarked revenues except in the areas of transportation and water supply, and
(5) the limiting capacity of the state's general economy to support further capital and operating expenditures.

A summary and conclusion will follow after all the work indicated has been completed.

OUTLINE OF STUDY

I. Introduction
   A. Short descriptive survey of selected beneficial uses of Kaneohe Bay.
      1. Recreational activities.
      2. Commercial fisheries.
   B. Major purpose and scope of this study.

II. Function of The State Water Quality Standards Program Relative to Fiscal Budgeting for Water Quality Conservation
   A. Review of the Standards Program.
   B. Imperfections and uncertainties.
   C. Interrelationships between the Standards Program and budgeting for water quality conservation.

III. Fiscal Problems of Financing The Standards Program
   A. State-local fiscal structure.
   B. State-local long term debt structure.
   C. Major fiscal problems related to the financing of the Standards Program.
      1. Availability of federal assistance programs.
      2. Use of general revenue surpluses for cash expenditures in capital improvement projects.
      3. Distribution of general excise tax revenues in the form of state grants to counties.
      4. Lack of general use of earmarked revenues except in the areas of transportation and water supply.
      5. Limiting capacity of the state economy to undertake capital improvement projects.

IV. Summary and Conclusions

SUMMARY AND PROJECTION

by

Vernon E. Brock

Nathan C. Burbank, Jr.

Doak C. Cox

Jack R. Davidson

L. Stephen Lau

Work on the various subprojects involved in the study of the pollution of Kaneohe Bay and its consequences has proceeded to varying extents depending in part on the availability of manpower and equipment and in part on the climate of the Bay and its tributary drainage area during the first six months of the study.

The distribution of sediments is being investigated through studies of sediment concentration and its transport in the waters of the Bay and its tributary streams and studies of sedimentary deposits in the Bay.

Sediment samples of water in the Bay have so far suggested that suspended-sediment transport involving sand-size particles, mainly carbonates, may be of significance. This conclusion needs, however, to be checked during the flood season and sampling for confirmation is planned together with current metering if necessary.

A major effort during the winter must go into flood sampling on streams entering the Bay because the bulk of the terrestrial sediment delivered to the Bay is likely to be introduced in flood periods. Special plans have to be made for such sampling because the flood peaks are extraordinarily short, generally much less than an hour in duration. Additional well-briefed manpower must be available on call for flood forecast periods and plans are being drafted for coordinating the project efforts in such a sampling program with those of other concerned agencies.

Distribution maps showing concentrations of the significant sediment mineral types in the sedimentary deposits will be used not only to indicate the relative importance, place to place, of sediment contributions of terrestrial and marine origin, but, so far as possible, details of the sediment sources.

A pattern of stations in the Bay was selected for the collection of water-quality samples including those needed for the studies of plankton and other microorganisms, and dissolved organics and other chemical-quality parameters. Enough data have been collected in these studies to reach some tentative conclusions.

In terms of species diversity and plankton biomass, the Bay can be divided into six regions, one of which, the barrier reef, can be reasonable excluded from further consideration for neritic plankton studies because of its shoal nature. The others are influenced by the ocean, land runoff, and sewage discharge in varying degrees which is, in turn, reflected in the character of the plankton communities present. Changes in any of these three sources of imputs into the Bay can be expected to be reflected by changes in the plankton communities. For example, that region of the Bay enriched by sewage has the highest plankton biomass and the lowest species diversity. If the area of enrichment increases, a parallel change in the structure of the plankton communities could be anticipated.

In the next six months the plankton communities of the southern and the central region of the Bay will be carefully compared since the major environmental difference between them is apparently the substantial discharge of sewage in the southern region. This comparison should provide information on the effects of eutrophication of the Bay by sewage and provide a basis for estimating the possible consequences of an increased flow of sewage into the Bay.

The dissolved organic material in the Bay is of diverse origin, being derived in part from the discharge of sewage into the Bay. As such, above some level of concentration, it is a component of sewage pollution with potentially deleterious effects on the biota. Its role in the bay ecosystems is of interest. Laboratory work has demonstrated that contact with bubbles and fine particles of calcium carbonate will cause some fraction of dissolved organics to precipitate from solution as particulate organic matter. Organic matter of this origin might be more available to particulate feeders and to bacteria in particulate form than when in solution and thus the removal of dissolved organics from solution may serve to reduce their effect as a pollutant and permit their utilization by organisms. The field work has, however, so far failed to confirm the significance of this process at sewage effluent discharge points.

The microbiological and chemical analyses reveal that at both of the two points at which sewage is discharged into the Bay, the microbiological standards set under the water quality act are consistently violated. The operation of the Kaneohe Marine Corps Air Station sewage treatment plant has been under special scrutiny because it does not maintain uniform operation as indicated by bacterial counts.

There is evidence that the concentrations of fecal streptococci and coliforms are higher for the stream and nearshore waters than at the discharge outfall of the Kaneohe sewage treatment plant. The concentrations of fecal streptococci in the streams and nearshore waters vary with the storm runoff pattern.

High rainfall, the presence of nutrients, and the presence of organic matter in runoff has been found to trigger a reduction in oxygen tension in the lower reaches of the streams tributary to the Bay. The nutrient load of the tributary streams at periods of low stream discharge appears to stimulate phytoplankton growth. The nutrient levels set as a water quality standards are exceeded in the Bay on occasion.

Continuance of the sanitary quality and nutrient studies will provide needed material for further evaluation of the water quality standards. It appears that a re-evaluation must be made of nutrient levels in the Bay and the Bay's productivity. The discharge of wastes into the Bay appears to have little effect at this time. Efforts will be concentrated on the correlation of the production of organics, phytoplankton production, conversion rates of nutrients to other compounds, and the mineralization of the wastes.

In the study of alternative methods for waste disposal, which will involve utilization and interpretation of data collected by other sub-projects, progress to date has consisted of the development of a detailed work plan, collection and review of background information, establishing future population projections, and ascertaining that the data being gathered by other sub-projects will be adequate for estimating the costs of the alternative methods.

The further work of the study of alternatives will involve close cooperation and coordination with the other studies, especially that of economics. In particular, the following investigations will be made with respect to sewage effluent disposal: characterization of effluents, Bay water, and environmental factors; prediction of the quality of the mixed water; development and evaluation of the engineering feasibility of alternative methods for disposal with respect to Hawaii Water Quality Standards; and cost estimation of capital improvements and operating expenses. With respect to stream water disposal, the engineering feasibility of alternative methods of control by watershed management and stream management will be investigated and cost estimates will be made of necessary capital improvements and operating expenses. For the alternative methods of waste disposal of both types, estimates will be made of resulting quality of the Bay water by zones.

A preliminary survey of commercial fishing and recreational uses of Kaneohe Bay has been completed. Data on commercial fishing has been collected and tabulated for nehu, fishpond catches, and other commercial catches. This data is represented in terms of seasonal or annual quantities and values for each commercial species reported to the State Fish and Game Division for a statistical area which is generally coincident with Kaneohe Bay.

Recreational activities have been found to be centered around several points around the Bay, including the Kaneohe Yacht Club, Kaneohe Bay Marina, Heeia Kea Pier, Kaneohe Marine Corps Air Station, and numerous private piers along the shoreline. Data has been obtained from the first three. Further information must be obtained from the Air Station and the State Harbors Division which has records on private piers.

The analysis in progress on economic feasibility focuses on the relationship between the standards and the sources of funds which are available for implementing the program of pollution control. A continual review of the overall water quality standards program has been in progress, and the various criteria separated in order to relate them to their respective funding source. For our purpose, the various sources of funds have been lumped into a water quality conservation budget. At the federal level, several major funding sources have been identified. In addition to the Interior Department (FWPCA grants), other major sources are the USDA (small watershed protection and flood control program), HUD (water and sewer facilities grant program), and the Department of Commerce (public works and development facilities program). At the state and local levels, the respective fiscal and debt structures have been summarized and key problem areas identified. A major part of our remaining effort on this aspect of the study will be devoted to digging deeper into the issues which underlie each problem area and relate them to the economic feasibility analysis. In addition, the physical and biological data being generated by the other subprojects must be reviewed and incorporated into the overall economic analysis.

A year is an extremely short period in which to analyze not only the ecology of Kaneohe Bay, but the complex ecological effects of increasing pollution resulting urban development in its tributary drainage area, and the still more complex socio-economic implications of such effects. in our study we intend not only to perform these analyses but to estimate future trends under various assumptions as to alternative means of waste disposal and drainage in the area. Although much is left to be done, even in the sampling and analysis of single ecological parameters, and more especially in the integration of the findings of the separate investigations underway, the results of the first half year encourage the belief that the results of the completed study will provide a satisfactory basis for initial managerial decisions.

It has been obvious from the beginning that there was insufficient knowledge, even to plan in detail, the research required to provide a more lasting basis for management. Certainly this brief study, when complete, will provide a much clearer picture of the more extensive investigations required.

PART III. BIBLIOGRAPHY

assembled by

Lawrence C. Gordon, Jr.

BIBLIOGRAPHY

BIOLOGICAL STUDIES

Anonymous. 1901. *Report of the U.S. Commission of Fish and Fisheries.* Washington, D.C. p. 479.

Anonymous. 1936. When pearls were found at Pearl Harbor. *Paradise of the Pacific,* 48(11):17.

Au, D. W. 1965. *Survey of the Distribution of the Eggs and Larvae of the Nehu in Pearl Harbor.* University of Hawaii. M. S. Thesis No. 428.

Bosch, H. F. 1965. A gastropod parasite of solitary corals in Hawaii. *Pacific Science,* 19:267-268.

Bosch, H. F. 1967. *Growth Rate of Fungia Scutaria in Kaneohe Bay, Oahu.* University of Hawaii. M. S. Thesis. 38 p.

Brock, E. 1953. *Annual Progress Report for Hawaii Investigation.* Project No. F-5-R-1. Creel Census. Hawaii Div. Fish and Game. 20 p.

Brock, V. E. 1954. A preliminary report on a method of estimating reef fish populations. *J. Wildlife Management,* 18(3):297-308.

Brock, V. E. and T. C. Chamberlain. 1968. Ecological and ecological reconnaissance off western Oahu, Hawaii, principally by means of the research submarine. *Pacific Science,* 22:373-394.

Chun, M. J. 1968. *Characteristics of a Tuna Cannery Waste.* University of Hawaii. M. S. Thesis No. 666.

Cobb, J. N. 1902. *Commercial Fisheries of the Hawaiian Islands.* Report U.S. Fish Commission (1901). pp.353-499.

Cobb, J. N. 1905. *The Commercial Fisheries of the Hawaiian Islands in 1903.* GPO. Washington. pp. 473-478.

De Ausen, T. T. 1966. *Coastline Ecosystems in Oahu, Hawaii.* University of Hawaii. M. S. Thesis No. 495.

Doty, M. S. 1957. Rocky intertidal surfaces. *Geol. Soc. Amer. Memoir 67,* 1:535-585.

Doty, M. S. 1959. Phytoplankton photosynthetic periodicity as a function of latitude. *J. Mar. Biol. Assoc. India,* 1(1):66-68.

Doty, M. S. 1967a. Contrast between the pioneer populating process on land and shore. *Bull. So. Calif. Acad. Sci.,* 66(3):175-194.

Doty, M. S. 1967b. *Improvement and Application of Benthic Algae Isotope Productivity Measuring Methods.* University of Hawaii. Hawaii Botanical Science Paper No. 3. n.p.

Doty, M. S. 1967C. Pioneer intertidal population and the related general vertical distribution of marine algae in Hawaii. *Bluemea*, 15(1):95-105.

Doty, M. S., R. R. Guillard and E. C. Jones. 1954-1955. The productivity of the inshore waters in Hawaii (Abstract). *Proc. Hawaii Acad. Sci.* University of Hawaii Publication.

Doty, M. S. and D. Mueller-Dombois. 1966. The biology of fresh, brackish and saline waters as it contributed to tropical delta formation. In *Scientific Problems of the Humid Tropical Zone Deltas and Their Implications.* Proc. of the Dacca Symposium. UNESCO, Paris. pp. 253-256.

Edmundson, C. H. 1928. The ecology of an Hawaiian coral reef. *B. P. Bishop Mus. Bull. 45.*

Edmundson, C. H. 1929. Growth of Hawaiian corals. *B. P. Bishop Mus. Bull. 58.*

Edmundson, C. H. 1933. Quantitative studies of copepods about the shores of Oahu. *Fifth Pacific Sci. Congr.* pp. 1997-2001.

Edmundson, C. H. 1937. Quantitative studies of copepods in Hawaii with brief surveys in Fiji and Tahiti. *B. P. Bishop Mus. Occas. Papers*, 13(12):131-146.

Edmundson, C. H. 1944. Incidence of fouling in Pearl Harbor. *B. P. Bishop Mus. Occas. Papers*, 18(1):1-34.

Edmundson, C. H. 1946. Reef and shore fauna of Hawaii. *B. P. Bishop Mus. Spec. Paper 22.* 381 p.

Ego, K. 1953. *Life History of the Fresh Water Gobies.* Project No. F-4-R-1. Hawaii Div. Fish and Game. Annual Progress Report. 13 p.

Fujimura, T. 1960. *Reef and Inshore Game Fish Management Research.* Underwater survey of fishing areas. Job Completion Report. Project No. F-5-R. Hawaii Div. of Fish and Game. 12 p.

Gordon, M. and H. M. Kelley. 1962. Primary productivity of an Hawaiian coral reef; a critique of flow respriometry in turbulent waters. *Ecology*, 43(3):473-480.

Iha, T. H. 1960. *Survival of Sewage Bacteria in the Sea.* University of Hawaii. M. S. Thesis.

Ikehara, I. I. 1961. *Billy Weaver Shark Research and Control Program.* Final Report. Hawaii Div. of Fish and Game. 25 p.

Ingram, W. M. 1937. *Fouling Organisms in Kaneohe Bay and Pearl Harbor, Oahu.* University of Hawaii. M. A. Thesis No. 150.

Johannes, R. E. 1963. *Uptake and Release of Phosphorus by Representatives of a Coastal Marine Ecosystem.* University of Hawaii. Ph. D. Thesis No. 42.

Kami, H. 1958. *Reef and Inshore Game Fish Management Research. Preliminary Study of Food and Feeding Habits of Reef Fishes.* Job Completion Report. Project N. F-5-R. Hawaii Div. of Fish and Game. 9 p.

Kohn, A. J. and P. Helfrich. 1957. Primary organic productivity of a Hawaiian coral reef. *Limnol. Oceanogr.*, 2(3):241-251.

MacCaughey, V. 1918. A survey of the Hawaiian coral reefs. *The Amer. Naturalist*, 52:409-438.

Manar, T. A. 1966. *Progress in 1964-65 at the Bureau of Commercial Fisheries Biological Laboratory, Honolulu.* U.S. Dept. of the Interior. 42 p.

Manar, T. A. 1967. *Progress in 1965-1966 at the Bureau of Commercial Fisheries Biological Laboratory, Honolulu.* U.S. Dept. of the Interior. Cir. 274. 51 p.

Morita, C. M. 1965. *Freshwater Fishing in Hawaii.* Hawaii Div. of Fish and Game. n.p.

Nakamura, E. L. 1965. *Synopsis of Biological Data on Hawaiian Species of Stolephorus.* U.S. Bureau of Commercial Fisheries Biological Laboratory, Honolulu. 52 p.

Nakamura, R. 1968. An additional contribution to the biology of the aholehole, Kuhlia sandvicensis (Steindachner). *Pacific Science*, 22:493-496.

Nemoto, C. N. 1960. *Reef and Inshore Game Fish Management Research. Underwater Survey of Fishing Areas.* Job Completion Report. Project No. F-5-R-7. Hawaii Div. of Fish and Game. 13 p.

Piyakarnchana, T. 1965. *The Plankton Community of the Southern Port of Kaneohe Bay, Oahu, with the Special Emphasis on the Distribution Breeding Season and Population Fluctuation of Sagitta Enflata Grassi.* University of Hawaii. Ph. D. Thesis.

Praseno, D. 1968. *A Study of Phytoplankton Seasonal Variations in Kaneohe Bay, Oahu, Hawaii.* Botany V-1968.

Randall, J. E. 1958. *Reef and Inshore Game Fish Management Research. Studies of the Food and Feeding Habits of Exotic Marine Game and Food Fishes.* Job Completion Report. Project No. F-5-R. Hawaii Div. of Fish and Game. 12 p.

Sakuda, H. M. 1964. *Experimental Purification of Easter Oyster (Crassostrea virginica) in Hawaii.* Hawaii Div. of Fish and Game. 16 p.

Sakuda, H. M. 1966a. Condition of American oyster, Crassostrea virginica, in West Loch, Pearl Harbor, Hawaii. *Trans. Amer. Fisheries Soc.*, 95(4):426-429.

Sakuda, H. M. 1966b. Reproductive cycle of American oyster, Crassostrea virginica, in West Loch, Pearl Harbor, Hawaii. *Trans. Amer. Fisheries Soc.*, 95(2):216-218.

Sparks, A. 1963. *Survey of the Oyster Potential in Hawaii.* Dept. of Land and Natural Resources. Hawaii Div. of Fish and Game.

State Fish and Game Division. *Study of Oyster Resource in Hawaii.*

Stokes, J. F. B. 1909. Walled fish traps of Pearl Harbor. *B. P. Bishop Mus. Occas. Papers*, 4(3):23-26.

Takata, M. and T. Fujimura. 1958. *Reef and Inshore Game Fish Management Research.* Annual progress report for continuing jobs. Project No. F-5-R-5. Hawaii Div. of Fish and Game. 3 p.

Tester, A. L. 1951. The distribution of eggs and larvae of the Anchovy Stolephorus purpuresus, Fowler, in Kaneohe Bay, Oahu, with a consideration of the sampling problem. *Pacific Science*, 5(4):321-346.

Tester, A. L. 1955. Variation in egg and larva production of the Anchovy, Stolephorus purpuresus, Fowler, in Kaneohe Bay, Oahu, during 1950-1952. *Pacific Science*, 9(1):31-41.

Tomich, *et al.* 1968. Ecological factors on Manana Island, Hawaii. *Pacific Science*, 22:284-428.

Tseu, W. S. L. 1953. Seasonal variations in the physical environments of the ponds at the Hawaii Marine Laboratory and the adjacent waters of Kaneohe Bay, Oahu. *Pacific Science*, 7(3):278-290.

Wald, F. (n.d.). *Taxonomy of Oahu Cryptophyceae.* University of Hawaii. M. S. Thesis.

Walsh, G. E. 1967. An ecological study of a Hawaiian mangrove swamp. *Estuaries.* G. H. Lauff (ed.). AAAS Publication No. 83. Washington, D.C.

Whipple, J. A. 1966. *The Comparative Ecology of the Hawaiian Littorina Perussac (Mollusca: Gastropoda).* University of Hawaii. Ph. D. Thesis. (Order No. 66-13, 713). Ann Arbor. Univ. Microfilms. 355 p. (Diss. Abstr. 27:2928).

COASTS: GENERAL STUDIES, GEOLOGY AND SAND BUDGET

Chamberlain, T. 1968. Littoral sand budgets. *Pacific Science*, 22:161-183.

City and County of Honolulu. *City Zoning Code.*

Corps of Engineers. 1910. *Hanapepe Bay, Island of Kauai, Hawaii.* 61st Congress, 2nd Session. House of Representatives Doc. No. 833. U.S. Government Printing Office.

Corps of Engineers. 1964. *Hawaiian Island Beaches.*

Corps of Engineers. (n.d.) *Joint Inspection of Coastal Projects in State of Hawaii.*

Department of Health, State of Hawaii. 1966a. *Public Hearing on Standards of Water Quality for the Kaneohe Bay Area, the Kailua Bay Area, the Waimanalo Bay Area.*

Department of Health, State of Hawaii. 1966b. *Public Hearings No. II-IV on Water Uses and Standards of Water Quality for Oahu's Water.*

Department of Health, State of Hawaii. 1967a. *Public Hearings No. I-II on Water Uses and Standards of Water Quality for Kauai and Niihau Waters.*

Department of Health, State of Hawaii. 1967b. *Public Hearings on Water Uses and Standards of Water Quality for Maui County Waters.*

Department of Health, State of Hawaii. 1967c. *Public Hearings on Water Uses and Standards of Water Quality for Hawaii County Waters.*

Department of Health, State of Hawaii. 1967d. *Public Hearings on Water Uses and Standards of Water Quality for State of Hawaii (2 Vols.)*

Department of Planning and Economic Development. 1963. *Hawaii Shoreline.*

Moberly, R. 1963a. *Coastal Geology of Hawaii.* Hawaii Institute of Geophysics Report No. 41. pp. xii-216.

Moberly, R. 1963b. Rate of denudation in Hawaii. *J. of Geology,* 71(3):371-375.

Moberly, R., Jr. 1968. Loss of Hawaiian littoral sand. *J. Sed. Petrol.,* 38(1):17-34.

Moberly, R. and T. Chamberlain. 1964. *Hawaiian Beach Systems.* HIG-64-2.

Planning Department, City and County of Honolulu. *General Plan Oahu.*

State Department of Planning and Research. 1962. *Shoreline Recreation Study-1962.*

CURRENTS AND TIDES IN THE HAWAIIAN ISLANDS

Doty, M. S. and J. C. Archer. 1950. An experimental test of the tide factor hypothesis. *Amer. J. Bot.,* 37(6):458-464.

Laevastu, T., D. E. Avery, and D. C. Cox. 1964. *Coastal Currents and Sewage Disposal in the Hawaiian Islands.* Hawaii Institute of Geophysics. HIG-64-1.

Latham, R. C. 1967. *Kauai Channel Currents.* University of Hawaii. M. S. Thesis No. 619.

Marine Advisors, Inc. 1965. *Littoral Processes and Shore Protection at Kahului Harbor, Maui, Hawaii.* Dept. of Transportation, Harbors Div.

Strong, C. C. and R. G. Skolmen. 1963. Origin of drift logs on the beaches of Hawaii. *Nature,* 197(4870):890.

Wallace, G. C., L. Cunha, J. Chu, T. Kohler, A. Moss and G. Reeves. 1951. *Report on Ocean Current Studies for Sand Island Outfall Sewer, Honolulu, Oahu, T. H.* Div. of Sewers. City and County of Honolulu.

Wyrtki, K. and V. Graffe. 1967. The approach of tides to the Hawaiian Islands. *J. Geophys. Res.*

ECONOMIC SURVEYS

Belt, Collins and Associates, Ltd. 1962. *Kalihikai - Hanalei, Kauai.* Prepared for: Lihue Plantation Company, Ltd.

Cajski, T. A. 1964. *The Ports of Kauai.* University of Hawaii. M. A. Thesis No. 558.

Hitch, T. K., S. Chu, and B. Hirogawa. 1959. *Current and Anticipated Developments Affecting Pop'n., Eco. Activity and Land Use on Kauai, Maui, Hawaii 1965, 1970, 1975.* Prepared for: Belt, Collins and Associates.

ENGINEERING REPORTS: HARBORS

Belt, Collins and Associates, Ltd. 1962. *Kaiaka Bay Small Boat harbor, Waialua, Oahu.* Prepared for: Harbors Division, Dept. of Transportation.

Corps of Engineers. 1964. *Coasts of the Hawaiian Islands.* 88th Congress, 2nd Session. House of Representatives Doc. No. 353. U.S. Government Printing Office.

Corps of Engineers. 1965a. *Honolulu Harbor and Barbers Point Harbor, Oahu, Hawaii.* 89th Congress, 1st Session. House of Representatives Doc. No. 93. U.S. Government Printing Office.

Corps of Engineers. 1965b. *Kawaihae Harbor, Hawaii.* 89th Congress, 1st Session. House of Representatives Doc. No. 75. U.S. Government Printing Office.

Hover, P. 1961. *Field Report on Oceanographic Aspects--Hawaii Kai Marina.*

Lublin, McGaughy and Associates. 1962. *Plan of Development for Sampan Harbor, Wailoa River, Hilo, Hawaii.*

ENGINEERING STUDIES: SEWAGE REPORTS

Anonymous. (n.d.). *Engineering Investigation Report for Improvement to Pearl Harbor Sewerage System, Pearl Harbor, Oahu.* Report to U.S. Navy Dist. Public Works Office. 14th Naval District.

Austin, Smith and Associates. 1961a. *Proposed Pearl City Sewage Treatment Plant, Ewa, Oahu.*

Austin, Smith and Associates. 1961b. *North Honolulu Sewerage Studies.* Prepared for: The Div. of Sewers. City and County of Honolulu.

Austin, Smith and Associates and Metcalf and Eddy. 1961. *Final Report on Pearl City Treatment Plant.*

Belt, Collins and Associates, Ltd. 1961. *Hilo Sewer System Study.* Prepared for: Dept. of Public Works.

Belt, Collins and Associates, Ltd. and Harland, Bartholomew and Associates. 1960. *Engineering Feasibility Studies.* Part One of the Comprehensive Plan for Ala Moana Reef, Honolulu, Hawaii. Prepared for: The Dept. of Land and Natural Resources. State of Hawaii.

Belt, Collins and Associates, Ltd. and Kennedy Engineers - San Francisco. 1961. *South Honolulu Sewerage Study.* Prepared for: The City and County of Honolulu.

Belt, Collins and Associates, Ltd. and Kennedy Engineers - San Francisco. 1962. *Hilo Sewerage Master Plan 1962-1992.* Prepared for: The County of Hawaii.

Division of Sewers. 1958. *A Report on Sewerage Master Plan for Waipahu, Ewa, Oahu.* Department of Public Works. City and County of Honolulu.

Gerakas, A. 1961. *Kailua, Kona, Sewerage System County of Hawaii.* Econ. Res. and Development Committee and Board of Supervisors. County of Hawaii and State Dept. of Econ. Development.

Herschler and Randolph. 1962. *Study of Pollution in Kahului Bay, Maui, Hawaii.* Report to the Dept. of Health. State of Hawaii. Data Supplement.

Holmes and Narver, Inc. and Belt, Collins and Associates, Ltd. 1959. *Kailua Ocean Outfall Sewer Ocean Portion.* Prepared for: Dept. of Public Works.

Kaiser Engineers. 1959. *A Review of Preliminary Design Sewage Treatment and Ocean Disposal for the Hawaii Kai Development.* Water Resources Engineers, Inc. Berkeley, California.

Metcalf and Eddy Engineers. 1944. *Report to Honolulu Sewerage Commission on Sewerage Disposal.* Vols. I and II.

Sunn, Low, Tom and Hara, Inc. 1963. *General Plans: Water, Sewerage and Drainage (County of Kauai).*

Sunn Low, Tom and Hara, Inc. 1964. *Report on Oceanographic Study for Kapaa Ocean Sewer Outfall, Kapaa, Kauai.* Dept. of Land and Natural Resources. Div. of Water and Land Development.

R. M. Towill Corporation. 1966a. *Design Report for Waimanalo Core Development Sewer Outfall Waimanalo, Koolaupoko, Oahu, Hawaii.* Prepared for: Dept. of Land and Natural Resources. Div. of Water and Land Development.

R. M. Towill Corporation. 1966b. *Ocean Outfall Report, Waimanalo Core Development.* Dept. of Land and natural Resources. Div. of Water and Land Development.

R. M. Towill Corporation. 1967. *Report on Oceanographic Survey and Study Relative to Sewage Disposal for Waialua--Haleiwa, Oahu, Hawaii.* Dept. of Public Works.

Water Resources Engineers, Inc. 1959. *A Review of Preliminary Design Sewage Treatment and Ocean Disposal for the Hawaii Kai Development.* Berkeley, California.

POLLUTION AND WATER QUALITY STUDIES

Burbank, N. C., Jr., P. L. Chan and R. F. Young. 1967. *Removal of Color From South Kohala Water: Island of Hawaii.* Tech. Report No. 14. Water Resources Research Center. University of Hawaii, Honolulu. 22 p.

Eldridge, E. 1963. *Report of Research and Resource Needs on Water Quality Problems in Hawaii.* U.S. Dept. of Health, Education and Welfare. Public Health Service Region IX.

Eto, M. A., *et al.* 1967. *Behavior of Selected Pesticides with Percolating Water in Oahu Soils.* Tech. Report No. 9. Water Resources Research Center. University of Hawaii, Honolulu. 35 p.

Federal Water Pollution Control Administration. 1967a. *Immediate Water Pollution Control Needs Coastal Waters of Hawaii County, Hawaii.* U.S. Dept. of the Interior. 27 p.

Federal Water Pollution Control Administration. 1967b. *Immediate Water Pollution Control Needs, Coastal Waters of Maui County, Hawaii (Islands of Maui, Molokai, Lanai, and Kahoolawe).* U.S. Dept. of the Interior. 39 p.

Federal Water Pollution Control Administration. 1967c. *Immediate Water Pollution Control Needs for the County of Honolulu, Islands of Oahu, Midway, French Frigate Shoales and Other Small Islands, Hawaii.* U.S. Dept. of the Interior. 48 p.

Federal Water Pollution Control Administration. 1967d. *Immediate Water Pollution Control Needs of Coastal Waters of Kauai County, Hawaii (Islands of Kauai and Niihau).* U.S. Dept. of the Interior. 48 p.

Gundersen, K. R. and D. B. Stroupe. 1967. *Bacterial Pollution of Kaneohe Bay, Oahu.* Tech. Report No. 12. Water Resources Research Center. University of Hawaii, Honolulu. 24 p.

Hawaii Division of Fish and Game. 1953a. *A Preliminary Pollution Survey of Honolulu Harbor.* 10 p.

Hawaii Division of Fish and Game. 1953b. *Survey of Industrial and Agricultural Wastes Discharged into the Coastal Waters of Maui.* Special Report to the Legislature. Territory of Hawaii. 11 p.

Hawaii State Department of Health, Environmental Health Division. 1967 *Recent Data on Water Quality by State Department of Health for Certain Maui Waters.*

Holdover Committee. 1949. *Subcommittee on Harbors, Airports and Public Utilities: Report Relating to the Pollution of Shore Waters Including Their Tributaries.* Territory of Hawaii. Vol. I.

Honolulu Chamber of Commerce. 1946. *Hawaii's Sanitation Problems.* Public Health Committee. Postwar Planning Committee on Health.

Knaeffer, T. 1968. Waste--and the rape of paradise. *Honolulu Star-Bulletin.* p. B 01.

Kumagai, J. S. 1966a. *Phosphate Determination of Kaneohe Bay Samples.* Tech. Mem. Report No. 7. Water Resources Research Center. University of Hawaii, Honolulu. 12 p.

Kumagai, J. S. 1966b. *Phosphate Determination on Some Waimanalo Seawater Samples and Some Kaneohe Bay Samples.* Tech. Mem. Report No. 6. Water Resources Research Center. University of Hawaii, Honolulu. 10 p.

Kumagai, J. S. 1967. *A Survey of Literature on Ground Water Recharge And Sulfide Generation.* Tech. Report No. 5. Water Resources Research Center. University of Hawaii, Honolulu. 41 p.

Lum, F. C. H. 1967. Hawaii water-quality standards seek control of sediment pollution. *Soil Conservation,* 33(2):33-34.

Smith, R. L. 1964. Water pollution in Pearl Harbor: steps to reverse the trend. *Water Sewage Works,* 3:318-323 (see also 324-326).

SUGAR WASTES

Bhaskaran, T. R. and R. N. Chakrabarty. 1966. Pilot plant for treatment of cane-sugar waste. *J. Water Pollution Control Federation,* 38(7):1160-1169.

Burns, R. 1967. *Investigation of Three Sugar Mills.* FWPCA Hawaii Water Quality. Unpublished.

Cox, D. C. 1954. *Water Development for Hawaiian Sugar Cane Irrigation.* Hawaii Planters' Record, 54(4):175-197.

Hawaiian Sugar Planters' Association. *Hawaii Cane Sugar Pamphlet.*

Hull, W. J. 1955. Mill waste disposal methods and comparative costs. Hawaiian Sugar Technologists. *Reports.* 14:55.

Immisch, G. B. 1964. *Land Reclamation and the Role of the Hydroseparator in Ewa Plantation.* University of Hawaii. M. A. Thesis No. 565.

Kennedy Engineers. 1967. *Report on Hawaiian Sugar Factory Wastes Receiving Water Study.* Prepared for: Hawaiian Sugar Planters' Association.

McGovern, M. T. 1967. *Statement on Sugar Factory Waste Treatment.*

Pintler, H. 1967. *Sugar Cane Mill Wastes in the State of Hawaii. A Review of the Problem.* U.S. Dept. of Health, Education and Welfare. Region IX.

WATER RESOURCES

Andrews, C. B. and W. D. Alexander. 1954. *The Structure of the Southeastern Portion of the Island of Oahu with Theories Concerning Artesian Wells.* Geology Dept. Experiment Station H.S.P.A. pp. 1-18.

Board of Water Supply, City and County of Honolulu. 1963. *Oahu Water Plan.*

Bowles, S. P. 1967. *Hydrologic Investigation of the Kaenoki Wells.* Water Resources Div. Board of Water Supply. City and County of Honolulu. 7 p.

Dale, R. H. 1967. *Land Use and Its Effect on the Basal Water Supply, Pearl Harbor Area, Oahu, Hawaii 1931-1965.* U.S. Geological Survey Dept. of the Interior Atlas HA-267.

Davis, R. T. 1960. *Major Streams of Kauai and their Utilization.* University of Hawaii. M. A. Thesis No. 424.

Department of Land and natural Resources, Division of Water and Land Development. 1963. *Flood Control and Flood Water Conservation in Hawaii.* Vol. II.

Department of Land and Natural Resources, Division of Water and Land Development. 1963. *Preliminary Summary of Findings in Water Resources Studies on Windward Oahu, Hawaii.*

Harland, Bartholomew and Associates. 1958. *Pearl Harbor Regional Drainage.* Prepared for: District Public Works Office, 14th Naval District, Pearl Harbor, Oahu, T. H.

Hawaii Water Authority. 1959. *Water Resources in Hawaii.*

Mink, J. F. 1964. Ground water temperatures in a tropical island environment. *J. of Geophysical Research,* 69(24):.

Palmer, H. S. 1946. *The Geology of the Honolulu Ground Water Supply.* Board of Water Supply. City and County of Honolulu, Hawaii. 55 p.

Stearns, H. T. 1931. *Preliminary Report on the Pearl Harbor Springs, Oahu, T. H.* First Progress Report of the Territorial Planning Boards.

Stearns, H. T. and K. N. Vaksvik. 1935. *Geology and Ground Water Resources of the Island of Oahu, Hawaii.* U.S. Geological Survey, Oahu, T. H.

U.S. Geological Survey. *Compilations of Records of Surface Waters of Hawaii, July 1950 through June 1960.* U.S. Dept. of the Interior. U.S.G.S. No. 1739.

U.S. Geological Survey. 1966. *Water Resources for Hawaii and other Pacific Areas.* U.S. Dept. of the Interior.

Visher, F. N. and J. F. Mink. 1964. *Ground Water Resources in Southern Oahu, Hawaii.* Geological Survey Water Supply Paper 1778.

Wentworth, C. K. 1928. Principals of stream erosion in Hawaii. *J. of Geology,* 36(5):385-410.

Wentworth, C. K. 1951. *Geology and G. W. Resources of Honolulu, Pearl Harbor Area - Oahu, Hawaii.* Board of Water Supply. City and County of Honolulu. 111 p.

WASTE DISPOSAL PROBLEMS AND FACILITIES

Pintler, H. E. 1965. *A Proposed Technical Assistance Project--Major Industrial Waste Disposal Problems in the State of Hawaii.* U.S. Dept. of Health, Education, and Welfare. Public Health Service. Region IX.

U.S. Department of Health, Education, and Welfare. 1960. *Waste Water Disposal Practices at Federal Installations.* Vol. 12, Hawaii.

U.S. Department of Health, Education, and Welfare. 1962. *Inventory of Municipal Waste Facilities.* Department of Health. State of Hawaii.

HONOLULU HARBOR STUDIES

Corps of Engineers. 1965. *Honolulu Harbor and Barbers Point Harbor, Oahu, Hawaii.* U.S. Government Printing Office.

Hawaii Division of Fish and Game. 1953. *A Preliminary Pollution Survey of Honolulu Harbor.* 10 p.

KANEOHE BAY STUDIES

Bathen, K. H. 1968. *A Descriptive Study of the Physical Oceanography of Kaneohe Bay, Oahu, Hawaii.* Tech. Report No. 14. Hawaii Institute of Marine Biology. University of Hawaii, Honolulu.

Bosch, H. F. 1967. *Growth Rate of Fungia Scutaria in Kaneohe Bay, Oahu.* University of Hawaii. M. S. Thesis. 38 p.

Department of Health, State of Hawaii. 1966a. *Public Hearing on Standards of Water Quality for the Kaneohe Bay Area, the Kailua Bay Area, the Waimanalo Bay Area.*

Gordon, M. and H. M. Kelly. 1962. Primary productivity of an Hawaiian coral reef; a critique of flow respirometry in turbulent waters. *Ecology*, 43(3):473-480.

Gundersen, K. R. and D. B. Stroupe. 1967. *Bacterial Pollution of Kaneohe Bay, Oahu.* Tech. Report No. 12. Water Resources Research Center. University of Hawaii, Honolulu. 24 p.

Ingram, W. M. 1937. *Fouling Organisms in Kaneohe Bay and Pearl Harbor, Oahu.* University of Hawaii. M.A. Thesis No. 150.

Piyakarnchana, T. 1965. *The Plankton Community of the Southern Part of Kaneohe Bay, Oahu, with the Special Emphasis on the Distribution, Breeding Season and Population Fluctuation of* Sagitta Enflata *Grassi* University of Hawaii. Ph. D. Thesis.

Praseno, D. 1968. *A Study of Phytoplankton Seasonal Variations in Kaneohe Bay, Oahu, Hawaii.* Botany V-1968.

Tester, A. L. 1951. The distribution of eggs and larvae of the Anchovy Stolephorus purpuresus Fowler, in Kaneohe Bay, Oahu, with a consideration of the sampling problem. *Pacific Science*, 5(4):321-346.

Tester, A. L. (n.d.). Variation in egg and larva production of the Anchovy, Stolephorus purpuresus, Fowler, in Kaneohe Bay, Oahu, during 1950-1952. *Pacific Science*, 9(1):31-41.

Tseu, W. S. L. 1953. Seasonal variations in the physical environment of the ponds at the Hawaii Marine Laboratory and the adjacent waters of Kaneohe Bay, Oahu. *Pacific Science*, 7(3):278-290.

Walsh, G. E. 1967. An ecological study of a Hawaiian mangrove swamp. *Estuaries*. G. H. Lauff (ed.). AAAS Publication No. 83. Washington, D.C.

PEARL HARBOR STUDIES

Anderson, H. W. 1962. *A Program for Watershed Management Research in Hawaiian Wildlands.* Tech. Paper No. 72. U.S. Dept. of Agriculture. Forest Service Pac. Southwest Forest and Range Exp. Station. 15 p.

Andrews, C. B. and W. D. Alexander. 1954. *The Structure of the Southeastern Portion of the Island of Oahu with Theories Concerning Artesian Wells.* Geology Dept. Experiment Station. H.S.P.A. pp. 1-18.

Anonymous. 1901. *Report of U.S. Commission of Fish and Fisheries.* Washington, D.C. p. 479.

Anonymous. 1936. When pearls were found at Pearl Harbor. *Paradise of the Pacific*, 48(11):17.

Anonymous. (n.d.). *Engineering Investigation Report for Improvement to Pearl Harbor Sewerage System Pearl Harbor, Oahu.* Report to U.S. Navy District. Public Works Office. 11th Naval District.

Reproduced from best available copy.

Au, D. W. 1965. *Survey of the Distribution of the Eggs and Larvae of the Nehu in Pearl Harbor.* University of Hawaii. M. S. Thesis No. 428.

Austin, Smith and Associates and Metcalf and Eddy. 1961. *Final Report on Pearl City Treatment Plant.*

Bowles, S. P. 1967. *Hydrologic Investigation of the Kaenoki Wells.* Water Resources Division. Board of Water Supply. City and County of Honolulu. 7 p.

Dale, R. H. 1967. *Land Use and Its Effect on the Basal Water Supply, Pearl Harbor Area, Oahu, Hawaii 1931-1965.* U.S. Geological Survey. Dept. of the Interior. Atlas HA-267.

De Ausen, T. T. 1966. *Coastline Ecosystems in Oahu, Hawaii.* University of Hawaii. M. S. Thesis No. 495.

Department of Health, State of Hawaii. 1966b. *Public Hearings No. II-IV on Water Uses and Standards of Water Quality for Kauai and Niihau Waters.*

Department of Land and Natural Resources. 1963. *Flood Control and Floodwater Conservation in Hawaii - Vol. II.*

Division of Sewers. 1957 and 1958. *A Report on Sewerage Master Plan for Waipahu, Ewa, Oahu.* Department of Public Works. City and County of Honolulu.

Edmundson, C. H. 1944. Incidence of fouling in Pearl Harbor. *B. P. Bishop Mus. Occas. Papers,* 18(1):1-34.

Harland Bartholomew and Associates. 1958. *Pearl Harbor Regional Drainage Study.* Prepared for: District Public Works Office. 14th Naval District. Pearl Harbor, Oahu, T. H.

Ingram, W. M. 1937. *Fouling Organisms in Kaneohe Bay and Pearl Harbor, Oahu.* University of Hawaii. M. A. Thesis No. 150.

Johannes, R. E. 1963. *Uptake and Release of Phosphorus by Representatives of a Coastal Marine Ecosystem.* University of Hawaii. Ph. D. Thesis No. 42.

Mink, J. F. 1964. Groundwater temperatures in a tropical island environment. *J. of Geophysical Research,* 69(24).

Palmer, H. S. 1946. *The Geology of the Honolulu Groundwater Supply.* Board of Water Supply. City and County of Honolulu, Hawaii. 55 p.

Sakuda, H. M. 1964. *Experimental Purification of Eastern Oyster (Crassostrea Virginica) in Hawaii.* Hawaii Div. of Fish and Game. 16 p.

Sakuda, H. M. 1966a. Condition of American oyster, Crassostrea virginica, in West Loch, Pearl Harbor, Hawaii. *Trans. Amer. Fisheries Soc.,* 95(4): 426-429.

Sakuda, H. M. 1966b. Reproductive cycle of American oyster, Crassostrea virginica, in West Loch, Pearl Harbor, Hawaii. *Trans. Amer. Fisheries Soc.*, 95(2):216-218.

Smith, R. L. 1964. Water pollution in Pearl Harbor; steps to reverse the trend. *Water Sewage Works*, 3:318-324, 324-326.

Stearns, H. T. 1931. *Preliminary Report on the Pearl Harbor Springs, Oahu, T. H.* First Progress Report of the Territorial Planning Boards.

Stearns, H. T. and K. N. Vaksvik. 1935. *Geology and Groundwater Resources of the Island of Oahu, Hawaii.* U.S. Geological Survey. Oahu, T. H.

Stokes, J. F. B. 1909. Walled fish traps of Pearl Harbor. *B. P. Bishop Occas. Papers*, 4(3):23-26.

U.S. Geological Survey. (n.d.). *Compilations of Records of Surface Waters of Hawaii, July 1950 Through June 1960.* U.S. Dept. of the Interior. U.S.G.S. No. 1739.

U.S. Geological Survey. (n.d.). *Investigations of Floods in Hawaii.* U.S. Dept. of the Interior.

Wentworth, C. K. 1928. Principals of stream erosion in Hawaii. *J. of Geology*, 36(5):385-410.

Wentworth, C. K. 1951. *Geology and G. W. Resources of Honolulu, Pearl Harbor Area, Oahu, Hawaii.* Board of Water Supply. City and County of Honolulu. 111 p.

White, S. E. 1949. The processes of erosion on steep slopes of Oahu, Hawaii. *Amer. J. of Science*, 247:168-186.

KAHULUI HARBOR STUDIES

Department of Health, State of Hawaii. 1967b. *Public Hearings on Water Uses and Standards of Water Quality for Maui County Waters.*

Herschler and Randolph. 1962. *Study of Pollution in Kahului Bay, Maui, Hawaii.* Report to the Dept. of Health. State of Hawaii.

Marine Advisors, Inc. 1965. *Littoral Processes and Shore Protection at Kahului Harbor, Maui, Hawaii.* Dept. of Transportation, Harbors Division.

HILO BAY STUDIES

Belt, Collins and Associates, Ltd. and Kennedy Engineers - San Francisco. 1962. *Hilo Sewerage Master Plan 1962-1992.* Prepared for: County of Hawaii.

Bureau of Sanitary Engineering. 1953. *Report on the Sanitary Status of Bathing Areas in Hilo Bay.* Dept. of Health. Div. of Sanitation.

Department of Health, State of Hawaii. 1967c. *Public Hearings on Water Uses and Standards of Water Quality for Hawaii County Waters.*

Lublin, McGaughy and Associates. 1962. *Plan of Development for Sampan Harbor, Wailoa River, Hilo, Hawaii.*

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